# DEVEOLPMENT OF AN ASSESSMENT MODEL USING AHP TECHNIQUE FOR RAILROAD PROJECTS EXPERIENCING SEVERE CONFLICTS IN KOREA

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**Abstract**: Though rail transit has many merits as a safe, environmental harmonic and scheduled transit, there are many problems to construct railroads because of the public resentment. However, there is no reasonable way to settle the conflict properly and it causes enormous social and economic losses. This paper suggests a methodology to evaluate public complaint using the AHP technique, which is generally used as the multi-criteria Decision Making (MCDM). However, the result from the AHP has some defects to control conflicts because the interests related to railroad projects are so complex that it is hard to make people persuaded easily. Therefore, this paper suggests "the improvement ranking method", "the sensitive analysis", and "the assessment of independence relationship" which can aid the basic AHP to be robust. And the AHP, modified by fuzzy method, is also suggested to apply this methodology to example rail paths in Korea.

**Keywords**: railroad, public complaint, AHP

# 1. INTRODUCTION

## 1.1 Background

Rail transit system has many advantages like mass transportation, safety, on-schedule arrival and departure. However, there are a lot of problems with constructing railroad. As the concern about the environment and safety is deepening the public complaints about railroad construction are increasing. However, there is no reasonable method to evaluate the public complains and to take a proper action, and consequently it makes a lot of social and economical loss.

However, the method to evaluate the public complaints has not been development. Because railroad construction is involved to many groups the agreement between the interest groups is very difficult. In addition, if the railroad project for national benefit is disturbed by complaint of some regions, it could bring about another nation-wide problems. Therefore it is very important to solve the problems with reasonable procedure as soon as possible.

With this background we try to develop reasonable assessment method in this study. In other words, we make assessment model using Analytic Hierarchy Process (AHP), which is one of Multi Criteria Decision Making (MCDM) techniques. However, AHP has some strict assumptions and one of them is that the evaluating elements should be independent with each other.

In this study we suggest a methodology to consider the dependency of the real socioeconomic variables for the AHP application. The fuzzy method is used to reflect the degree of dependency and the sensitivity analysis for weighted score is also carried out. Then the priority of improvement is calculated to prevent another public complaints. The result of this study can be applied usefully when public complaint is lodged against railroad construction project.

## 1.2 Contents and Scope

The purpose of this study is to develop method for assessment of railroad project. To accomplish this aim, we investigate and analyze a lot of public complaints related to railroad projects. Then several alternatives are considered to find out the most suitable alternative for each case.

The qualitative evaluating elements, as well as quantitative ones, should be considered to assess reasonably and the AHP is selected after careful examination of several techniques. Then the degree of dependency is reflected to the AHP model by the fuzzy theory and priority of improvement is calculated from the modified AHP model.

## 2. LITERATURE REVIEW

### 2.1 Analytic Hierarchy Process technique

The AHP technique can evaluate qualitative, quantitative and intuitive criteria comprehensively, and it is possible to raise the level of confidence of it through carrying out consistency testing. The AHP technique resembles the structure of human brain, and obtains quantitative results by transforming the comparative weight between elements to ratio scale. The AHP technique is based on three principles; hierarchical structuring, weighting, logical consistency.

Pair-wise comparison, homogeneity, independence relation, and expectation are basic assumptions of AHP technique (Vargas, 1990). They are very important and should be used properly when applied to AHP technique because they are the fundamental frames of the AHP technique logically and actually.

Pair-wise comparison means that decision maker can not only compare one element of a project or policy with another but also determine the weighted score between them. Homogeneity means that the weighted score can be presented by settled index in fixed range, and independence relation means that there is no relationship among elements. Expectation means that hierarchical structure logically corresponds to the expectation of every decision makers.

After considering many factors relative to railroad projects, decision makers calculate the total weighted score sum of each element in each alternative, and then the best alternative can be concluded.

Researchers survey citizens, citizen groups, project operators, and government officers who have enough knowledge and experience to judge the public benefit impartially. Consistency test of the questionnaire result is carried out, and they are applied for calculating the weighted score of the each object.

**2.2 Fuzzy Theory**

1) Basic Theory

In this study, Fuzzy theory is applied to consider the dependency problem in AHP model based on the study of Song, et al. (2003) The study is as follow.

In Cartesian product $A \times A$, $d$ is the first dimensional cross fuzzy dependence relationship, and the $d(i,j)$ matrix means the degree of dependence relationship between two evaluation criteria $i$ and $j$. Fuzzy dependence relationship is reflective ($d(i,i) = 1, \forall a_i, a_j \in A$), and is defined as follows.

- Evaluation criterion $a_i$ is perfectly subordinated to evaluation criterion $a_i$.

$$d(j,i) = 1 \qquad , \ \omega_i \geq \omega_j \qquad (1\text{-}1)$$

$$d(i,j) = \omega_j / \omega_i \qquad , \ \omega_i \geq \omega_j \qquad (1\text{-}2)$$

- Evaluation criterion $a_i$ is partially subordinated to Evaluation criterion $a_i$.

$$d(j,i) = \text{ between 0 and 1} \qquad , \ \omega_i \geq \omega_j \qquad (2\text{-}1)$$

$$d(i,j) = d(j,i) \times (\omega_j / \omega_i) \qquad , \ \omega_i \geq \omega_j \qquad (2\text{-}2)$$

- Evaluation criteria $a_i$ and $a_j$ are independent from each other.

$$d(i,j) = d(j,i) = 0 \qquad , \ \forall a_i, a_j \in A \qquad (3)$$

Then, the cross-weighted score of the degree of dependency is calculated as follows.

$$\omega_{ij} = d(i,j) \times \omega_i \qquad (4)$$

Computation of the cross-weighted score of the degree of dependence relationship is iterated until there isn't fuzzy dependency. The cross-weighted score of criteria should be distributed by each evaluation criteria. Here, $Bel$ and $Pl$ measurements can be used for distributing the degree of dependence relationship between criteria. $Bel$ and $Pl$ measurements are given as follows;

$$Bel(A) = \sum_{B \subset A} m(B) \qquad (5\text{-}1)$$

$$Pl(A) = \sum_{B \cap A \neq \phi} m(B) \qquad (5\text{-}2)$$

Using these Fuzzy measurements, it is possible to fix the upper limit and lower limit of the total weighted score sum of each criterion in each alternative.

2) Model for Overlapping

• Model 1

Model 1 is based on the process, which includes the degree of dependence relationship into the computation process of the weighted score of the basic AHP technique using the matrix $d(i,j)$. This model excludes the overlapping portion from the pair-wise comparison matrix before calculating the weighted score. It is based on the supposition that the result from the only non-overlapping parts is correct outcome. Equation (6) shows the process.

$$(\omega_i / \omega_j)' = \omega_i / \omega_j \times (1 - d(i,j)) \qquad (6)$$

This method has the advantage of relatively easy computation, but the disadvantage of being unable to compare the improved result with the basic one.

• Model 2

In model 2, after calculating the weighted score through the present AHP technique, the degree of dependence relationship between criteria is distributed to the basic value by constant ratio. This model also has the same advantage of relatively easy process as model 1, so is appropriate for the case, which has the comparatively clear result. However, in this model there is the disadvantage that it distorts the result because of distributing the degree of dependence relationship by constant ratio. This model iterates the calculation process until there isn't overlapping portion between criteria, but equation (6) and equation (7) is the fundamental expressions when there are only two elements $i$ and $j$.

$$\omega_{ij} = \min(\omega_i, \omega_j) \times d(i,j) \qquad (7)$$

$$\omega_i^{'} = \omega_i - 1/2(\omega_{ij}) \qquad (8\text{-}1)$$

$$\omega_j^{'} = \omega_j - 1/2(\omega_{ij}) \qquad (8\text{-}2)$$

• Model 3

After computation of the weighted score through the present AHP technique, in model 3, the upper and the lower limit is decided using Fuzzy measurement, and the range of the final score of alternatives is fixed. This method decides the expectancy value of the upper and lower limit using $Bel$ and $Pl$ measurements based on the process of references 3, and settles the upper and lower limit value of each alternative. This model cannot fix the exact value, but is appropriate for the sensitive project because it has the advantage that all cases can be compared with.

$$y^*[g(b_i)] = \sum_{D \subset A} \omega(D) \cdot Max\ g(b_i, a_j) \tag{9}$$

$$y_*[g(b_i)] = \sum_{D \cap A \neq \phi} \omega(D) \cdot Min\ g(b_i, a_j) \tag{10}$$

where, $b_i$ is alternative $i$, $a_i$ is evaluation criterion $i$, $g$ is evaluation function, $\omega(D)$ is weighted score of evaluation criteria, $y^*[g(b_i)]$ is the upper limit of the score, and $y_*[g(b_i)]$ is the lower limit of the score.

## 3. MODEL DEVELOPMENT

### 3.1 Public Complaint Analysis And Select Alternatives

To investigate and analyze characteristics of public complaint, we examined several complaints raised with railroad, eg. Gyungui-line, Gyungchun-line, Suin-line, Changhang-line in South Korea. Then we divide them into 4 categories in accordance with their root cause.

Various opinions should be reflected to railroad projects and, to do this, the participation of several groups is necessary. Also alternatives which can prevent public complaints have to be selected. In this study, firstly, a lot of opinions of the professionals are collected and several alternatives are compared with public complaints. Lastly, alternatives are selected which can solve more than one complaint. (Table 1)

### 3.2 Appraise Alternatives Model

As a result of investigation the most suitable model to select the best alternative, the AHP is adopted in this study. Because the AHP technique reflects reasons of each complaint, it could bring reasonable result out.

It is very important to choose evaluating elements in AHP technique and, to set the elements, careful discussions are conducted between the professionals of various fields. The result of setting the elements are shown in Table 2. And all the evaluating elements from 1st to 3rd hierarchy are shown in Table 3.

Table 1. Feasible Alternatives Considering Public Complaint

| Complaint \ Alternative | Detour | Station | | Overpass | Underpass | Soundproof Wall | No Action |
|---|---|---|---|---|---|---|---|
| | | Relocate | Add | | | | |
| **Regional Bisection** | ○ | × | × | ○ | ○ | × | ○ |
| **Transportation System Degrade** | ○ | ○ | △ | ○ | ○ | × | ○ |
| **Noise / Vibration / Dust** | ○ | ○ | × | × | ○ | ○ | ○ |
| **Life Quality Decrease** | ○ | ○ | × | × | ○ | × | ○ |
| **Urban Planning Disagreement** | ○ | ○ | ○ | ○ | ○ | × | ○ |
| **Infringe Living Rights** | ○ | ○ | × | △ | △ | × | ○ |

### 3.3 Estimate Improvement Rank

Because all alternatives are related to lots of groups, it is hard to make an agreement between the various interest groups. Also because all the alternatives include some problems, we try to select most efficient and effective alternative. Although we can select best alternative using AHP, it has still some problems. To prevent other complaints or problems, two matters should be considered; problems to be able to occur and problem should be solved firstly.

During the process of AHP, the weighted score of the elements implies the level of superiority and inferiority simultaneously. Therefore the priority of the evaluating elements can be calculated from the weighted score. The procedure of calculating the priority is presented at Figure 1.

Table 2. Evaluating Elements

| **Alternative** | **Detour** | **Station** | **Overpass** | **Underpass** | **Soundproof Wall** | **No Changes** |
|---|---|---|---|---|---|---|
| **Evaluating Element** | -Bisection<br>-Transportation System<br>-Demand<br>-Cost | -Demand<br>-Cost<br>-Accessibility<br>-Urban Development<br>-Transportation System<br>-Environment | -Cost<br>-Regional Development<br>-Transportation System<br>-Envionment | -Environment<br>-Transportation System<br>-Urban Development<br>-Cost | -Cost<br>-Environment | -Use element of other alternative |

Table 3. Hierarchy of the Evaluating Elements

<table>
<tr><th>1st Level</th><th colspan="4">Transportation Network</th><th colspan="4">Regional Development</th><th colspan="3">Environment</th><th colspan="2">Transportation Demand</th><th colspan="3">Railroad Project</th></tr>
<tr><th>2nd Level</th><td colspan="2">Accessability</td><td>Safety</td><td>Effect to Network</td><td>Bisection</td><td colspan="3">Neighborhood Development</td><td>Noise / Vibrate</td><td>Air Pollution</td><td>Sunshine Disturb</td><td>Demand</td><td>B/C Analysis</td><td colspan="2">Cost</td><td>Profit</td></tr>
<tr><th>3rd Level</th><td>related transport modes</td><td>distance to approach</td><td>-</td><td>-</td><td>-</td><td>slum</td><td>CBD reform</td><td>station area reform</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>construct cost</td><td>com-pensate cost</td><td>-</td></tr>
</table>

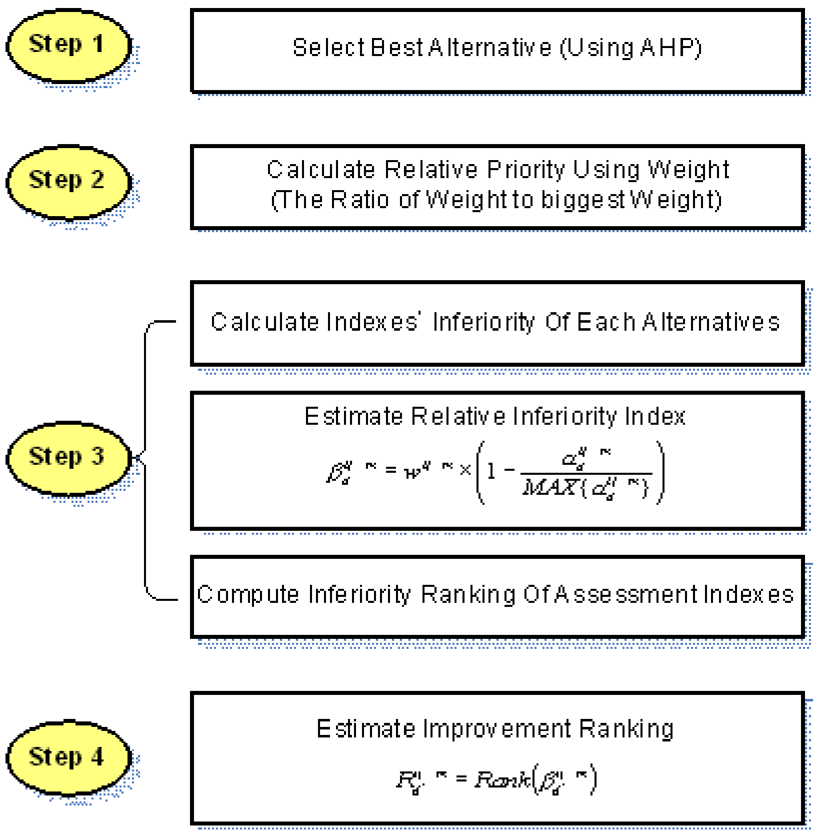


Figure 1. Procedure to Calculate the priority of Evaluating Elements

### 3.4 Degree of Dependency Estimation Model

The one of basic assumptions of AHP technique is that all the elements in same hierarchy are totally independent reciprocally. However this assumption is hard to be satisfied due to ambiguousness and complexity of questions. Besides this problem the evaluating elements include mutually dependent properties to a degree. More reliable result based on Song, et al. (2003) is derived to consider the effect of the degree of dependency.

### 3.5 Sensitivity Analysis

A lot of groups are involved in AHP, a group decision support system, survey. The organization of survey group can influence on the result significantly and, therefore, it is important to organize the group fairly.

Public officers, researchers, citizens, enterprise and so on are considered as members of AHP survey in railroad project. Among these groups public officers and researchers can be thought to have fairness and professional knowledge. Also, it is very important issue what ratio of each group's involvement is chosen. If specific group has significant involvement ratio, the result can be affected by that group's decision. So, when AHP is implemented, the ratio should be decided. However, because it is hard to decide the ratio it is suggested to apply the same ratio in the study of Korea Development Institute (KDI).

In this study, 4 groups (train experts, providers, citizens, local government officers) are selected and each group has 11 persons. It means that we assume each group has same weight of involvement. However, to consider the effect of constitution ratio, the sensitivity analysis is carried out to various weighted scores of each group. The ratio is specified to 3 categories, 50%, 100%, and 150% in this study.

## 4. CASE STUDY

### 4.1 Data Collection

To examine the application of AHP developed in this study, we choose two candidates of case study. One is Suin-line and the other is Gyungui-line in Korea. Because Suin-line has extremely conflict it is not proper to validate. So we select the Gyungui-line as sample case, especially Ilsan region. In present, Gyungui-line exists as a single lane, but provider tries to expand it as double lanes. In this region, many public complaints are made for the environment problem, traffic jam and regional bisection.

When survey is implemented, we provide general information about Gyungui-line to help people understand better. In survey there are two alternatives, "No Changes" and "Underpass". No changes means to construct double lanes on the ground. In survey 44 persons (11 persons per each group) answered and inconsistency are tested. If inconsistency index is over 0.15 point survey is implemented again to guarantee the reliance of the survey.

### 4.2 Result

1) Best Alternative

Firstly, evaluating elements of the AHP are decided by brainstorming of professionals. And then, the weighted scores of the evaluating elements are surveyed with pair-wise comparison in each hierarchy. Also the weighted scores of each alternative are surveyed separately. To calculate the score of alternative, we use the geometric mean of weighted scores.

As result of total questionnaires, the weighted scores of ‘Transportation System’ is 0.244, ‘Urban and Regional Development’ is 0.242, ‘Environment’ is 0.180, ‘Demand’ is 0.186 and ‘Railroad Project’ is 0.148 in 1$^{st}$ hierarchy. They consider ‘Transportation System’ and ‘Urban and Regional Development’ as the most important element to assess railroad construction project. The total score of ‘Underpass’ is 0.489 and ‘No Changes’ get 0.511 point. ‘No Changes’ is selected better alternative, however, the gap of scores is very small. So it is hard to say that ‘No Changes’ is much prior to ‘Underpass’.

2) Degree of Dependency Analysis

If the dependency among the elements exists, it can distort the result significantly. So, to raise reliance of AHP, it is need to consider the effect of the degree of dependency between elements. In this study, we investigated the dependency of each hierarchy and reflected that to Model 1, 2 and 3. The result is shown at Table 5.

Table 5 shows alternatives’ scores reflected the dependency. As seen below, results are different to a degree according to the models. In basic AHP, ‘No Changes’ was selected to best alternative as 0.511 score. In other models, however, ‘Underpass’ is better than ‘No Changes’. This result shows the best alternative can be changed by the degree of dependency. Therefore this reversion should be considered when gap of scores is relatively small. This problem may be solved with reorganization of questions or resurvey of weights.

3) Improvement Rank

The alternative selected through the AHP technique is the best alternative relatively, not absolutely. Because the best alternative still has demerits, it is needed to improve demerits of the best alternative to prevent another complaint. To make it, we have to find out the most serious reason of complaint objectively. Also, improvement ranking should be ordered to execute policy efficiently.

Using improvement rank model developed in this study, we suggested the rank of the improvement of the best alternative. (Table 6)

Table 4. Alternatives Analysis (Total)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1st Level** | **Transportation System** | | | | **Urban or Regional Development** | | | | **Environment** | | | **Demand** | | **Railroad Project** | | | **Sum** |
| | 0.244 | | | | 0.242 | | | | 0.180 | | | 0.186 | | 0.148 | | | 1.000 |
| **2nd level** | Accessibility | | Safety | Effect to Other Transport System | Bisection | Environs Development | | | Noisy &Vibration | Air Pollution | Sunshine Disturbance | Demand Comparison | B/C Ratio | Cost | | Earning Rate | |
| | 0.432 | | 0.276 | 0.291 | 0.305 | 0.695 | | | 0.587 | 0.197 | 0.216 | 0.270 | 0.730 | 0.531 | | 0.469 | 5.000 |
| **3rd Level** | related modes | access distance | - | - | - | slum | CBD reforming | railway area reforming | - | - | - | - | - | Construction Cost | Compensation Cost | - | |
| | 0.600 | 0.400 | - | - | - | 0.172 | 0.510 | 0.319 | - | - | - | - | - | 0.498 | 0.502 | - | 3.000 |
| **Underpass** | 0.465 | 0.500 | 0.988 | 0.548 | 0.716 | 0.640 | 0.608 | 0.460 | 0.679 | 0.635 | 0.658 | 0.500 | 0.082 | 0.082 | 0.500 | 0.082 | 8.144 |
| **No Changes** | 0.535 | 0.500 | 0.012 | 0.452 | 0.284 | 0.360 | 0.392 | 0.540 | 0.321 | 0.365 | 0.342 | 0.500 | 0.918 | 0.918 | 0.500 | 0.918 | 7.856 |
| **Score** | | | | | | | | | | | | | | | | | **SUM** |
| **Underpass** | 0.029 | 0.021 | 0.066 | 0.039 | 0.053 | 0.018 | 0.052 | 0.025 | 0.072 | 0.023 | 0.026 | 0.025 | 0.011 | 0.003 | 0.020 | 0.006 | **0.489** |
| **No Changes** | 0.034 | 0.021 | 0.001 | 0.032 | 0.021 | 0.010 | 0.034 | 0.029 | 0.034 | 0.013 | 0.013 | 0.025 | 0.125 | 0.036 | 0.020 | 0.064 | **0.511** |
| SUM | | | | | | | | | | | | | | | | | 1.000 |

Table 5. Alternative Scores Considering Dependency (Total)

| | **Basic AHP** | **Model 1** | **Model 2** | **Model 3 - Max** | **Model 3 - Min** |
|---|---|---|---|---|---|
| **Underpass** | 0.4890 | 0.5213 | 0.5006 | 0.4996 | 0.5006 |
| **No Changes** | 0.5110 | 0.4787 | 0.4994 | 0.5004 | 0.4994 |
| **Sum** | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

Table 6. Rank of the Improvement of the Best Alternative

| | Weighted Score | Alternative | Sum of Score | Superiority | Inferiority | Inferior Index | Inferior Ranking |
|---|---|---|---|---|---|---|---|
| **Transportation System** | 0.2436 | Underpass | 0.1558 | 1.0000 | 0.0000 | 0.0000 | 2 |
| | | No Change | 0.0878 | 0.5634 | 0.4366 | 0.1063 | 1 |
| **Regional Development** | 0.2421 | Underpass | 0.1482 | 1.0000 | 0.0000 | 0.0000 | 2 |
| | | No Change | 0.0940 | 0.6342 | 0.3658 | 0.0886 | 1 |
| **Environment** | 0.1804 | Underpass | 0.1201 | 1.0000 | 0.0000 | 0.0000 | 2 |
| | | No Change | 0.0603 | 0.5023 | 0.4977 | 0.0898 | 1 |
| **Demand** | 0.1860 | Underpass | 0.0363 | 0.2425 | 0.7575 | 0.1409 | 1 |
| | | No Change | 0.1497 | 1.0000 | 0.0000 | 0.0000 | 2 |
| **Railroad Project** | 0.1479 | Underpass | 0.0286 | 0.2402 | 0.7598 | 0.1124 | 1 |
| | | No Change | 0.1193 | 1.0000 | 0.0000 | 0.0000 | 2 |

As a result, alternative ‘No Changes’ which is selected in AHP is inferior to ‘Underpass’ in regard of ‘Transportation System’, ‘Urban or Regional Development’ and ‘Environment’ elements. Inferior index of the best alternative, ‘No Changes’, show 0.1063 in ‘Transportation System’, 0.0886 in ‘Urban and Regional Development’ and 0.0898 in ‘Environment’ respectively. This result means that we should improve the ‘Transportation System’. ‘Environment’ and ‘Urban and Regional Development’ index.

‘Transportation System’ is made up of 3 evaluating elements ‘Accessibility’, ‘Safety’, and ‘Effect To Transportation Network’. When we examine merits and demerits of two alternatives, ‘No Changes’ has larger possibility to occur cross-section accident or obstruction road traffic. As considering circumstances of Gyungui-line, it is possible to say that the result of improvement rank model is reasonable.

4) Sensitivity Analysis

We divide the weight of groups into 3 categories, 0.5, 1.0, 1.5. 3 times of weight is not reasonable when the survey is carried by specialists. Although we separate weight with 0.5 gap, it is possible to change it for various object.

We try to validate robustness and application of model, not estimate the weight of groups. As a result of sensitivity analysis, it is possible to reverse in 28%, 23 over 81 cases. It means that the result of survey is reasonable more or less. When specific opinion has large weight relatively, reversion is occurred.

## 5. CONCLUSION AND SUGGESTION

The key findings of this study responding to the study objectives were summarized as follows.

1. We classify public complaints in accordance with reasons. Also we suggest 7 alternatives, include 'No Changes', which solve complaints.
2. We select AHP technique for assess public complaint in this study after examining several techniques. It is because AHP technique can consider public complaint well.
3. We develop inferior index which can rank the inferiority of alternatives. Using this index, improvement rank is calculated after AHP assessment. We calculated inferior index about only first hierarchy, but it can be expanded $n$ th hierarchy,
4. Overlapping is reflected to assessment model. The rank of alternatives could be changed by overlapping. Therefore when scores of alternatives don't have large gap, it is need to analyze with this overlapping. As resurvey weights of assessment indexes, overlapping could be reflected in AHP.
5. To validate our model we carried out sample survey in Gyungui-line, and model work well. There which were several public complaints regard with Gyungui-line. We carried out AHP technique with not only the geometric average but the arithmetical average, and we got same results. Also, we could have same rank according to relative and absolute priority ranking model of AHP. When we analyzed as classified groups, we can find out their characteristics and point of view about railway project.
6. Sensitivity analysis was operated to find change possibility of result by various weights of groups. After classifying groups 3 categories(50%, 100%, 150%), scores were recalculated. It could be changed of result at 23 cases over 81(23%).

To obtain more satisfactory results, some suggestions are given as follows:

Firstly, it is need to present concrete and feasible improvement way after calculating inferior index. Secondly, more discussion should be carried out among the specialists. Thirdly, objective method can verify the independence of assessment indexes. Lastly, it is need to additional study about standard values of group's weight when sensitivity analysis is done.

Nowadays there is a lot of public complaints regard to railway project, and it often prevents to carry out it. With the model developed in this study, it is possible to drive railway project efficiently and unify various opinions of several groups.

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