A Study on the High-Speed Railway Safety Evaluation using the F-AHP

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Abstract

The purpose of this study is to suggest a method to support decision making of researchers, when we estimate the safety of the high-speed railway using F-AHP. To apply this method, Korean type of high-speed railway was engaged, and the 8 Stages of accident type and the five criteria were suggested that we must meet.

Then, the interview with the researchers working for high-speed railway was used to confirm the alternatives suggested. The employed F-AHP for this study estimate using emotional words based on AHP of Saaty, so it is very good to estimate the high-speed railway safety.

1. Instruction

The high-speed railway is huge traffic system (vehicle), which is operated organically, and it is combining all the element, electric power, and controlled system, and it is much faster vehicle than others working on the ground. In case of high-speed vehicle, there could be some different working situations, so the high-speed railway could have problems we have not met before.

That is, even a small problem of mechanical part could leads a serious safety accident, so it must be controlled through a radical measure during development, design, and using it. Therefore, the safety factors must be the matter of highest priority. Also, the counter measures of safety must be built up at first according to the railway accident happened before.

The goal of safety must be set at first to secure the high-speed railway safety. AHP (Analytic Hierarchy Process) is employed to suggest alternatives under the multiple criteria in this study. The AHP suggested (Saaty in 1971) is a tool to support a decision-making including the personal opinion and intuition, and it is far easier than other method. Then, it has advantages that control the complex object having multiple criteria.

The features of AHP are that a decision maker decides by intuition and subjective to decide weight relatively between the criteria (upper layer) and the alternatives (lower layer) under the criteria, and Pairwise comparison is very important when it is decided. In here, human word was used as a result of Pairwise Comparison, and Saaty had suggested linier Pairwise comparison value (1~9) for that scale (Table 1).

Table 1. Meaning of Pairwise Comparison

Pairwise Value	Definition
1	equal importance
3	weal importance
5	strong importance
7	very strong importance
9	absolute importance
2,4,6,8	Intermediate values

2. The Criteria and alternatives of the high-speed railway

Hukuta [2] categorized the high-speed railway accident (alternatives) as follows.

• Stage I: Getting loss human life or many persons wounded.

• Stage II: Possibilities getting loss human life or many persons wounded.

• Stage III: Getting person wounded.

• Stage IV: Possibilities getting person wounded.

• Stage V: Harming the train or railway.

• Stage VI: Service failure more than 30 minutes.

• Stage VII: Service failure from 10 to 30 minutes

• Stage VIII: Service failure below 10 minutes.

Furthermore, Hukuta [2] carried out quantity estimation including five factors such as importance, frequency, stability, economical efficiency, and sociality. The meaning of each factor is as follows. According to those factors, we suppose to estimate the high-speed railway safety that F-AHP including human sensibility, which comes from AHP of Saaty.

3. Numerical Background

Now, let us define the upper layer factors set $U=\{U_1,\Lambda\ ,U_n\}$ and direct lower layer factors set of upper layer $L=\{L_1,\Lambda\ ,L_m\}$, then we assume that lower layer is estimated at the some point of upper layer factor. Then, let the Pairwise Comparison value be a_{ij} about a_i, a_j to get the weight $\omega_1,\Lambda\ ,\omega_n$ of the upper layer factors coming from AHP, then the Pairwise Comparison matrix of $U_1,\Lambda\ ,U_n$ must be $U=(a_{ij})$. Therefore, if we know the $\omega_1,\Lambda\ ,\omega_n$, the $\Delta=(a_{ij})$ is the Equation (1) shown below;

$$\Delta=\begin{pmatrix} \lfloor\omega_1/\omega_1\rfloor & \lfloor\omega_1/\omega_2\rfloor & \Lambda & \lfloor\omega_1/\omega_n\rfloor \\ & \lfloor\omega_2/\omega_2\rfloor & \Lambda & \lfloor\omega_2/\omega_n\rfloor \\ & & \Lambda & \mathrm{M} \\ & & & \lfloor\omega_n/\omega_n\rfloor \end{pmatrix} \quad (1)$$

where $\lfloor\bullet\rfloor$ is largest integer no greater than $\bullet$ (real part), and the left below of diagonal is inverse after $\lfloor\bullet\rfloor$.

Also, the overall weighting of the factor j of the lower layer is Equation (2) shown below, when the weight of the lower layer, which is estimated at the factor i of the upper layer by AHP, is considered as $\tau_i^1,\Lambda\ ,\tau_i^m$.

$$W^j=\sum_{i=1}^{n}\varpi_i,\quad (j=1,\Lambda\ ,m) \quad (2)$$

Saaty defined the C.I.(Consistency index) of the Pairwise Comparison matrix like Equation (3).

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

where, $\lambda_{\max}$ is maximized eigen-values, and the Pairwise Comparison matrix is $n\times n$.

Next, by using the Saaty AHP above, the decision making with the fuzzy emotion brought in the sensitivity of the human being is considered. . Since the result of decision making in Saaty AHP get only the same value so that it cannot control the judgment of action taken protectively, typically, positively or passively.

The judgment can be controlled by adding the human sensitivity value, and the expanded judgment AHP is considered. By adding the human sensitivity value, the judgment can be controlled and the expanded judgment AHP is considered. At this point of view, the parameter of the sensitivity value of a human being is used (Table 2).

The fuzzy transformation is performed using the Equation (4) for each element of upper level [7].

Table 2: Definition of μ

μ	Definition
0.0	absolute negative estimation
0.1	strong negative estimation
0.3	weal negative estimation
0.5	keep one's balance
0.7	weal positive estimation
0.9	strong positive estimation
1.0	absolute positive estimation

$$M = \begin{cases} [\xi], & s = 0, \\ \xi, & s = 1 \\ 1 - [1 - \xi], & s = \infty \\ (s^{\xi} - 1)/(s - 1), & otherwise \end{cases} . \quad (4)$$

where,

$$[\xi] = \begin{cases} 1, & 0 < \xi \le 1, \\ 0, & \xi = 0, \end{cases}$$

$$s = ((1/\mu) - 1)^2,$$

$$F_i = \sum_{i \in U} \varpi_i .$$

4. Section Survey and F-AHP Algorithm

• Step 1: The alternatives of evaluation entry are arranged on the level structure.

• Step 2: Pair-wise comparisons of the safety estimation among evaluation entries are performed.

• Step 3: Pair-wise comparisons of the alternatives under the each evaluation entry are performed.

• Step 4: In the pair-wise comparison matrix under the evaluation entries if the matching degree exists between the ranges of $0 \le C.I. \le 0.1$ the weight is that of the evaluation entry and advanced to Step 7.

• Step 5: If the weight of the evaluation entry is changed, make the weight of the evaluation entry 1 as criteria.

• Step 6: The pair-wise comparison matrix is changed by utilizing the Equation (1) generated from the modified weight in Step 5.

• Step 7: The parameter of the sensitivity value of a human being is determined (Table 2)

• Step 8: The weight of each alternative gained in Step 2 is arranged in descending order and compared with the corresponding weight of the evaluation entry.

• Step 9: The weight value of evaluation entries from top to bottom is added up one by one.

• Step 10: Fuzzy conversion is performed by utilizing the Equation (4).

• Step 11: With the weight value of pair-wise comparison of the alternative gained in Step 2, the difference of the weight value from the very bottom to the direct upper is calculated one by one.

• Step 12: The value of fuzzy conversion gained in Step 10 is multiplied in Step 11.

• Step 13: The overall weighting is evaluated among the evaluation entries.

5. The consequence of the safety evaluation by using the F-AHP.

Based on the explained algorithms in the Section 4, the sensitivity value of human is being changed consecutively, the result of the changed data of the corresponding total weight are depicted in Figure 1. To begin with, if μ is changed from 0.0 to 1.0, Stage Ⅰ constantly keeps the much superior level. Even though researchers for the high-speed railway judge the entire surrounding situation with time or efficiency, or judge negatively, positively, or in any case, the occurrence of the accidents involving the accident of the dead or the multiple wounded is inevitable, for the high-speed railway to be operated in the future.

It is predicted that to prevent the accidents prevention system needs to be implemented first.

Also in the case, $\mu < 0.6$, Stage Ⅰ ~ Stage Ⅷ have the importance of the order of weight but if the value of μ is increased, $\mu > 0.6$, the weight of Stage Ⅱ and Stage Ⅲ is reversed. In the case that the researchers for the high-speed railway make an action positively against an accident, Stage 2 has more importance than Stage 3, decision makers will be able to predict the safety of the possibility of the dead and the multiple wounded.

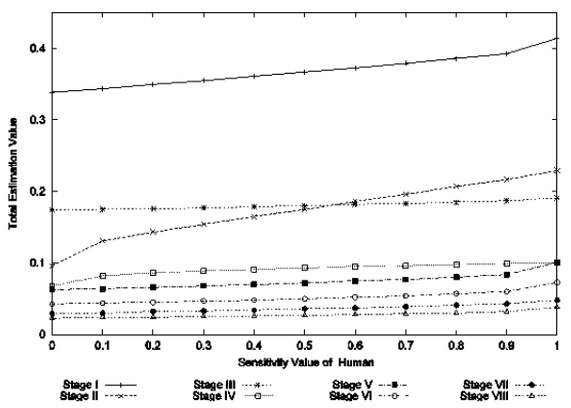

Fig 1. Whole Appearance of Overall Weighting when

6. Conclusion

The technique of safety evaluation of the high-speed railway by utilizing F-AHP has been done under investigation. This technique is for supporting the researcher's decision making of the safety of the high-speed railway. Recently the reason why AHP technique receives spotlight is that even though multiple entries in the technique exist. The complicated object is handled simply and easily. Also in the case of Saaty AHP, when only the sensitivity value $\mu = 0.5$ of a human being is used there is more or less difficulty in the decision judgment of the decision maker. However in the case of the use of evaluation of the F-AHP by changing the sensitivity value of a human being under the introduction of time, efficiency and many external elements, the decision maker more or less has advantage to make the optimum decision.

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