Analytic Hierarchy Process for Evaluation Weights on Occupational Safety and Hygiene Items in the Bridge Construction Site

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Abstract: This paper aims to evaluate key factors that associate Occupational Safety and Hygiene management during bridge constructions by the Analytic Hierarchy Process (AHP). Data were collected from experts’ questionnaires and conducted on the Expert Choice 2000 software. It finds that electrocution factor plays an important factor on this study rather than fall injury factor as one knows. The reason maybe cause by that electrocution events have less been reported by supervisor than fall injury events. This study found that the results from AHP analysis were partial consistent with traditional labor safety and hygiene assessment item that fall injury factor shows. Hence, it is ensured that AHP model has capacity to evaluate weights on occupational safety and hygiene management assessment items in bridge constructions and to provide more in-sighted objective (electrocution) on this topic.

1. Introduction

1.1. Occupational Safety and Hygiene Management in Bridge Constructions
Bridges have become an important transportation artery in modern cities. With the advancement of science and technology, the construction methods used to build bridges are changing with each passing day. Although the emerging bridges are beautiful in shape, their structures are not only complicated but also difficult to construct. If the design is bad, the quality will not match the expectations, and the waste of cost will even be the casualties of the construction workers. Ways to examine the effectiveness of its safety management. The construction project is a high-risk industry. How to prevent occupational disasters and ensure the safety and health of employees and contractors is an important goal of safety management.

1.2. Construction industry characteristics
According to the production time and production process of the construction industry, the product characteristics of the construction industry include: [1]
1. The production location is not fixed. Except for the concrete components, most of them must be built at each construction site.
2. Different engineering tools, materials, and techniques must be used for engineering production combinations and engineering properties.
3. The production time is long, and it belongs to outdoor work, so it is easy to be affected by the construction topography and weather.
4. In the production process, the division of labor is extensive, the composition of molecules is complex, and the integration of operational efficiency is the key to smooth engineering production.
Due to the nature of the construction industry, different construction machines, materials, and construction methods must be used to meet the needs of different projects, and improper management of accidents can occur.
1.3. Construction industry occupational disaster
Referring to the International Labor Statistics of the Ministry of Labor in Taiwan, 2014, the rate of deaths from occupational disasters in the construction industry in various countries was compared. The rate of deaths in occupational disasters in Taiwan's construction industry was 0.136% in 2014, 0.120% in 2013, and 0.131% in 2012. Compared with 101.7% in South Korea in 2012, 0.059% in Singapore, 0.021% in the United Kingdom, and 0.099% in the United States.

1.4. Causes of occupational disaster
In general, the proportion of unsafe behavior is high. I will list unsafe conditions and unsafe behaviors as follows: the unsafe condition includes Second, unsafe behavior includes:

1.5. Three key elements that constitute occupational disasters
There are as follows [2]
1. Facilities, trips, etc. caused by the work process.
2. The object is to engage in workers.
3. The result is disease (occupation), injury, disability, and death. The result is disease (occupation), injury, disability, and death. The result is disease (occupation), injury, disability, and death. The result is disease (occupation), injury, disability, and death [3]. The loss of occupational disasters can be divided into direct losses and indirect losses: indirect losses are also called hidden losses. The cost of the loss, including: Disasters will not only kill workers, but also cause huge economic losses. If we consider the loss of social impact caused by the changes in the families of the disaster-stricken workers, it will not be estimated [4] [5].

2. Exposition of Delphi Method and Analytic Hierarchy Process Method;

2.1. Delphi Method
The Delphi Method was developed 1948 by Rand Corporation of California. Originally proposed by Norman Dalkey and Olaf Helmer [6]. The theoretical basis is a research group composed of a group of experts and scholars. After several questionnaires, experts with inconsistent opinions can change the original opinions, and tend to answer most closely to experts' opinions, thus reach a consensus on topics of interest among all experts. After the questionnaire was answered, the opinions gradually became consistent and the subsequent analysis could be carried out [7].

2.2. Delphi implementation steps
Generally it can be summarized as the following steps: [8]
(1) Identify the research topic.
(2) Screening a number of experts or scholars in the research field to become a group.
(3) Produce and implement the first questionnaire.
(4) Organizing and retrieving the questionnaire, summarizing the results, and distributing the overall results to the original selected experts, asking them to consider the overall results and expressing their opinions again. This step can be repeated many times until the results of the group response are stable and consistent.
(5) Obtain the final balance.

2.3. The application of Delphi Method and Questionnaire
The original questionnaire of underfield method is designed to assess the overall indicators. Therefore, in addition to collecting and collating relevant domestic and foreign literatures, in order to improve the integrity and practicality of the questionnaire [9].

2.4. Analytic Hierarchy Process
AHP is a mathematic model to set up multi-choice items of interest problem by matric manners with numerical eigenvalue solving problems. AHP systematizes complex decision-making or planning problems and assigns hierarchical decomposition to different levels and ranks their hierarchy [10].

2.5. Details of Analytic Hierarchy Process
The key concept to use of the AHP can be written as follows.
The basic judgement scale originally proposed by Saaty [11] for the AHP consisted of the words: Equal, Weak, Strong, Very Strong, and Absolute [12-14].
Figure 1 shows sample AHP questionnaire form that can be created by google form and distributed to experts. And Table 1 gives the scale of relative importance given by Saaty [10] that will be set up in AHP questionnaires.

Table 1. Scale of relative importance according to Saaty in 1977,1980 [10]

| Intensity of important | definition          |
|------------------------|---------------------|
| 1                      | Equal importance    |
| 2                      | Weak                |
| 3                      | Weak importance     |
| 4                      | Moderate plus       |
| 5                      | Essential importance|
| 6                      | Strong plus         |
| 7                      | Very strong importance|
| 8                      | Very, very strong   |
| 9                      | Absolute Importance |

In a matrix form it was organized into positive reciprocal n x n matrix as $A_{n*n}$. The coefficients of resulting matrix of the pairwise comparison possess the necessarily reciprocal with $a_{ij} = 1$ and $a_{ij} = 1/a_{ji}$ as generalized. If we multiply the matrix with the vector of preference $w = (w_1, w_2, ..., w_n)$, we can obtain:

$$Aw = \lambda w$$

(1)

It is a eigenvalue problem, Eq. (1) must be solved. For consistent consideration, the evaluation need to check the matrix consistency, i.e., the input elements that may be given by statistic methods. Data collect form expert questionaires are linear independent. That can be referred to so called index of Consistency Index, C.I. [10]. As follows:

$$C.I. = (\lambda_{max} - n) / (n-1)$$

(2)

Where at the beginning the $\lambda_{max}$ (eigenvalue of the matrix) has to be determined. Saaty [10] proposed that then the Consistency Ratio, C.R. can be determined by

$$C.R. = \frac{C.I.}{R.I.}$$

(3)

Where R.I. can be referred to Saaty [15]. If the matrix is completely consistent then CI=0.

Saaty suggested another measure the CR (consistency ratio) that can be calculated like Eq. (3). In Eq.(3) R.I. is given by mean of CI values collected from a random simulation of Saaty pair-wise comparison matrices CIs. The suggested value of the CR should be no greater than 0.1. In general judgement scales used in AHP will play an important role on the matrices. Because of eigenvalues problems will be highly impacted by element values that were given by experts’ questionaires.
3. Data Collections

3.1. Hierarchy Criteria Objective Setup

1. Interview of the original facet content: After being the director of the safety management of bridge construction engineering and the personnel with relevant practical experience, each person proposed to discuss the important factors of safety management of bridge engineering construction from occupational disasters.

![Hierarchy with 3 criteria and 12 subitems]

Figure 2. Hierarchy with 3 criteria and 12 subitems

In short, for execution this study 12 questionnaires answered by 12 experts are considered. A checklist of criteria and subobjectives of AHP in Figure 2 is shown as below. Experts were asked to fill out a lot of pairwise comparisons in a questionnaire, this could be finished at different criteria levels using the preferential judgment scales as shown in Table 2 according to their thoughts and experiences on the pairwise comparison.
4. Discussion;

4.1. Simulation Results
In this research AHP results as shown tables (Table 2, Table3). It shows that electrocution plays an important factor on the first level criteria. It is different to that one knows. Most people believe that fall injury was the key factor in the bridge construction because many reports were made in the government administration reports. Meanwhile Table 3 shows that construction frame collapsed plays an important role in the second level criteria.

| First level criteria | weights | ranking |
|----------------------|---------|---------|
| Fall injury          | 0.336   | 2       |
| Electrocuton         | 0.357   | 1       |
| Collapse hazard      | 0.308   | 3       |
| Consistency check IR=0.00

| Index of evaluation                            | weights | ranking |
|------------------------------------------------|---------|---------|
| There is no security protection for the operation | 0.089   | 5       |
| The job does not have a safe upper and lower device | 0.099   | 4       |
| Site management airborne                       | 0.065   | 10      |
| Safety net is not set in the high position     | 0.083   | 7       |
| Electric machinery is not cleaned and maintained on time | 0.057   | 11      |
| Power-related equipment lacks inspection       | 0.102   | 3       |
| Ignore electricity safety                      | 0.111   | 2       |
| The power supply line is not covered with insulation | 0.086   | 6       |
| Construction frame collapsed                   | 0.121   | 1       |
| Excavation area collapse                       | 0.037   | 12      |
| The casing is not well reinforced              | 0.075   | 8       |
| Excavation does not grasp geological conditions| 0.075   | 8       |

5. Conclusions;
The study found that the results from AHP analysis were partial consistent with traditional occupational safety and hygiene performance evaluation items. So, AHP model has ability to evaluate weights that related to occupational Safety and Hygiene to optimize management objects.

Particularly, it found that electrocution factor plays an important factor on this study rather than fall injury factor as one knows. This reason may be caused by that electrocution events had been less reported by supervisor than fall injury events at sites.

In practice, based upon the analysis of AHP by input experts’ questionnaires, prime information about occupational safety and hygiene for the weights on each checklist is assessed. So one can effectively preventive tragedies on the construction of bridges on the management strategies. And measures can then be established to reduce the occurrences of accidents in the bridge construction project.

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