Application Research in Accident Classification Based on Fuzzy Evaluation System

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Abstract. In view of the fuzzy boundary problem in the criterion of accident grade classification, the number of deaths, the number of injuries and the direct economic losses of accidents are taken as evaluation elements respectively, and the judgment matrix of accident grade is constructed. The influence weight of indicators is calculated by AHP and the consistency of judgment matrix is checked. Taking some typical production accidents as an example, the membership function is constructed according to the existing accident indexes. In this paper, an accident grade classification method based on fuzzy evaluation system is put forward, and the accident evaluation matrix is obtained, and the accident grade is determined according to the principle of maximum membership degree. To a certain extent, it can provide scientific reference and reference basis for the qualitative analysis of accident grade.

1. Introduction
The determination of the accident level is divided into different scopes according to different classification principles. The consequences of an accident may belong to multiple categories at the same time. In order to ensure the scientific and fairness of the accident investigation results, it should be accurately determined according to the scientific and rational division principle. So it is necessary to use the fuzzy evaluation system for in-depth research.

Relevant scholars carried out detailed analysis and discussion on the classification of road traffic affairs. The fuzzy mathematics theory was used to comprehensively evaluate the multiple indicators of road traffic accidents. In the selection of evaluation indicators, the classification criteria of indirect economic loss accidents were introduced [1]. Feng-qin Li applied the fuzzy hierarchy theory to the gas outburst hazard analysis, comprehensively evaluated the established element sets, analyzed various indicators in detail, constructed the judgment matrix and relative weights, identified the most dangerous indicators and determined their outstanding dangers [2].

In view of the frequent occurrence of various types of accidents in China, comprehensive quantitative statistics and strict qualitative analysis are carried out on the consequences of accidents. Based on the known casualties and economic losses caused by accidents, the fuzzy evaluation method is not clear about the unclear existence. The problem is given to the system's argumentation analysis, and then the objective evaluation and supplement of the nature of the accident is judged, which has certain reference significance for the fairness of the accident investigation result.

2. Overview of Fuzzy Evaluation

2.1. Evaluation Method Basis
Under the principle of the same division, the number of casualties caused by a single accident and the
direct economic losses may belong to different divisions, which directly affect the fairness of the accident investigation results. The factors of the accident level should be comprehensively measured and utilized. The fuzzy definition of mathematics analyzes the different indicators of accidents, which can make up for the irrationality of the classification of the severity of accidents by a single index [3]. In this paper, fuzzy system theory is used to classify several representative production safety accident levels in the industry, and the membership function of fuzzy accident level is established, which gives a fuzzy evaluation method that can be used to define the accident level. Compared with other existing methods, this paper gives the method has obvious reference and complementary.

2.2. Influencing Factors Weight
Weight is the quantitative evaluation of the relative importance of each factor in fuzzy decision making. In order to eliminate subjective bias, the classical method of solving multi-objective decision-making problem--AHP is adopted, which ensures the objectivity of weight coefficient better [4]. Accuracy is the mathematical programming of decision makers for a complex decision-making process. It essentially determines the weighting effect of each indicator on the ultimate goal, and determines the final degree of influence of an element on the event itself [5]. The factors that determine the accident level when assessing the result of the accident level are: (1) the number of deaths; (2) the number of injured; (3) direct economic losses, according to the weight of the relevant experts on the factors affecting the accident, construct the judgment matrix $P$, namely:

$$
P = \begin{bmatrix}
1 & 4 & 9 \\
1/4 & 1 & 5 \\
1/9 & 1/5 & 1
\end{bmatrix}
$$

(1)

Using the MATLAB software's characteristic function $[v \ d]=eig(P)$, the maximum eigenvalue $\max=3.071$ is obtained, and the corresponding characteristic vector is $w=[0.947 \ 0.309 \ 0.081]^T$. The $w'$ is normalized to obtain $w=[w_1, w_2, w_3]= [0.708 \ 0.231 \ 0.061]$, the matrix $w$ at the time is the weight value of each indicator of the accident [6]. Then judge the matrix consistency index test, it need to calculate the consistency index value $CI=(\lambda_{\text{max}}-n)/(n-1)=0.0355$, and find out that the average third-order consistency index $RI=0.52$, then $CR=CI/RI = 0.0355/0.52 = 0.068 < 0.1$, the judgment matrix consistency test is passed.

3. Establish Fuzzy Evaluation Matrix
According to the relevant regulations of China’s "Production Safety Accident Report and Investigation and Handling Regulations" [7], production safety accidents are classified according to the number of casualties or direct economic losses as shown in Table 1.

| Accident indicator       | Accident level                      |
|--------------------------|-------------------------------------|
| number of deaths/$R_1$   | general accident $R_1<3$, bigger   |
| (Unit: person)           | accident $3 \leq R_1 < 10$, major  |
|                          | accident $10 \leq R_1 < 30$,       |
|                          | extraordinary accident $R_1 \geq 30$|
| number of injured/$R_2$  | $R_2<10$, $10 \leq R_2 < 50$, $50 \leq R_2 < 100$, $R_2 \geq 100$|
| (Unit: person)           |                                     |
| direct economic loss/$R_3$| $R_3<0.1$, $0.1 \leq R_3 < 0.5$, $0.5 \leq R_3 < 1$, $R_3 \geq 1$|
| (Unit: 10 million yuan)  |                                     |

Establishing indicator set $U= \{u_1, u_2, u_3\}=$ {number of deaths, number of injured, direct economic loss}, accident level set $V=\{v_1, v_2, v_3, v_4\}=$ {general accident, bigger accident, major accident, extraordinary accident}, the $i$-factor evaluation of the $i$-th ($i=1, 2, ..., 3$) indicators $R_i$ is $R_i= \{r_{i1}, r_{i2}, ..., r_{i5}\}$, which is regarded as a fuzzy subset on $V$; $r_{ij}$ ($i=1, 2, ..., 3; j=1, 2, ..., 4$) indicates that the $i$-th
index $u_{ij}$ is rated as the membership degree of the $j$-th level $v_i$, that is, the membership probability [8].

The judgment matrix formed by the indicator set and the comment set can be expressed as:

$$
R = \begin{bmatrix}
    r_{11} & r_{12} & r_{13} & r_{14} \\
    r_{21} & r_{22} & r_{23} & r_{24} \\
    r_{31} & r_{32} & r_{33} & r_{34}
\end{bmatrix}
$$

(2)

In the formula, $r_{ij} = U_i \{u_{i}, v_i\}$ ($0 < r_{ij} \leq 1$)

Fuzzy evaluation $B$ is a fuzzy subset on $V$, which can be written as:

$$
B = w \cdot R,
$$

that is:

$$
B = \left[ \begin{array}{ccc}
    w_1 & w_2 & w_3
\end{array} \right] \cdot \left[ \begin{array}{cccc}
    r_{11} & r_{12} & r_{13} & r_{14} \\
    r_{21} & r_{22} & r_{23} & r_{24} \\
    r_{31} & r_{32} & r_{33} & r_{34}
\end{array} \right]
$$

(3)

In order to avoid the data difference caused by subjectivity, the relevant data experience is used to establish the membership function of the four levels of indicators related to the severity of the accident. The accidents are classified into general accident, bigger accident, major accident, extraordinary accident according to the number of deaths. Its membership function is represented by $D_1(x), D_2(x), D_3(x), D_4(x)$, respectively, and is divided by trapezoidal fuzzy sets.

$$
D_1(x) = \begin{cases}
    1 & 0 \leq x < 3 \\
    (5-x)/2 & 3 \leq x < 5 \\
    0 & \text{others}
\end{cases}
$$

(4)

$$
D_2(x) = \begin{cases}
    x/2 & 3 \leq x < 5 \\
    1 & 5 \leq x < 10 \\
    (20-x)/10 & 10 \leq x < 20 \\
    0 & \text{others}
\end{cases}
$$

(5)

$$
D_3(x) = \begin{cases}
    x/10 & 10 \leq x < 20 \\
    1 & 20 \leq x < 25 \\
    (30-x)/5 & 25 \leq x < 30 \\
    0 & \text{others}
\end{cases}
$$

(6)

$$
D_4(x) = \begin{cases}
    x/10 & 25 \leq x < 30 \\
    1 & x \geq 30 \\
    0 & \text{others}
\end{cases}
$$

(7)

Similarly, in line with the number of injured people caused by production safety accidents, the accidents are classified into general accident, bigger accident, major accident, extraordinary accident.

The membership functions are $E_1(x), E_2(x), E_3(x), E_4(x)$ respectively. (x) indicates that trapezoidal fuzzy set partitioning is still used.

$$
E_1(x) = \begin{cases}
    1 & 0 \leq x < 10 \\
    (30-x)/20 & 10 \leq x < 30 \\
    0 & \text{others}
\end{cases}
$$

(8)

$$
E_2(x) = \begin{cases}
    x/20 & 10 \leq x < 30 \\
    1 & 30 \leq x < 50 \\
    (70-x)/20 & 50 \leq x < 70 \\
    0 & \text{others}
\end{cases}
$$

(9)

$$
E_3(x) = \begin{cases}
    x/20 & 50 \leq x < 70 \\
    1 & 70 \leq x < 90 \\
    (100-x)/20 & 90 \leq x < 100 \\
    0 & \text{others}
\end{cases}
$$

(10)

$$
E_4(x) = \begin{cases}
    x/10 & 90 \leq x < 100 \\
    1 & x \geq 100 \\
    0 & \text{others}
\end{cases}
$$

(11)

According to the size of the direct economic loss caused by the accident, the accident is divided into general accident, bigger accident, major accident, extraordinary accident. The membership function is represented by $F_1(x), F_2(x), F_3(x), F_4(x)$ respectively, still using trapezoidal fuzzy set.
According to the given accident statistics, the values of each factor are calculated separately and the specific element values of the evaluation matrix $R$ are obtained. After the weight calculation, the accident level can be determined according to the principle of maximum membership degree [9-11].

4. Example Application

Now select industry-specific production safety accidents as research objects, the construction accident was caused by the collapse of the “11.24” Power Plant construction platform of Fengcheng of Jiangxi province, the chemical accident of the “6.5” liquefied gas tank explosion accident of Petrochemical Co., Ltd at Jinyu of Shandong province, the road traffic accidents with Zhejiang province “7.23” Yong-wen line railway train rear-end accident as well as taking the “9.5” gas explosion accident in Yongdingzhuang Mine as an example (Table 2).

| Accident                                      | number of deaths (Unit: person) | number of injured (Unit: person) | direct economic loss (Unit: person) |
|-----------------------------------------------|---------------------------------|----------------------------------|-------------------------------------|
| the “11.24” construction platform of Jiangxi Fengcheng Power Plant | 73                              | 2                                | 1.0197                              |
| the “6.5” liquefied gas tank explosion accident of Petrochemical Co., Ltd | 10                              | 9                                | 0.4468                              |
| Zhejiang “7.23” Yong-wen line railway train rear-end accident | 40                              | 172                              | 1.9371                              |
| the “9.5” gas explosion accident in Yongdingzhuang Mine | 31                              | 16                               | 0.01                                |

The number of deaths, injuries, and direct economic losses in the accidents in Table 2 are taken into equations (4)-(7), (8)-(11), and (12)-(15), respectively. Judgment matrix of the collapse of the city power plant is:

$$R_1 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Judgment matrix of the “6.5” liquefied gas tank explosion accident of Petrochemical Co. Ltd at Jinyu of Shandong province is:
\[
R_2 = \begin{bmatrix}
0 & 1 & 1 & 0 \\
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0
\end{bmatrix}
\]

Judgment matrix of Zhejiang“7.23”Yong-wen line railway train rear-end accident is:

\[
R_3 = \begin{bmatrix}
0 & 0 & 0 & 1 \\
0.7 & 0 & 0 & 1 \\
0 & 1 & 0 & 0
\end{bmatrix}
\]

Judgment matrix of the “9.5” gas explosion accident in Yongdingzhuang Mine is:

\[
R_4 = \begin{bmatrix}
0 & 0 & 0 & 1 \\
0.7 & 0.8 & 0 & 0 \\
0 & 1 & 0 & 0
\end{bmatrix}
\]

The evaluation matrix of each accident can be calculated according to (3) of formula: \(B_1 = [0.231 \ 0 \ 0.231 \ 0 \ 0.061] , B_2 = [0.231 \ 0.708 \ 0.769 \ 0] , B_3 = [0.462 \ 0.061 \ 0.939] , B_4 = [0.223 \ 0.185 \ 0.0708] \). In accords to the principle of maximum membership degree, the four accidents can be graded as: extraordinary accident, extraordinary accident, major accident, and extraordinary accident. The evaluation results are consistent with the official conclusions, indicating that the fuzzy evaluation system determines the accident level has a high accuracy.

5. Conclusion
Based on the number of casualties and direct economic losses caused by production safety accidents, this paper uses AHP to establish a judgment matrix, and obtains the membership function according to the accident classification criteria to obtain the severity level of the accident. Combined with the full text, the following conclusions are drawn:

(1) According to the comprehensive consideration of the weight of the factors affecting the accident by experts in the field, it can be known that the number of deaths caused by the accident, the number of injured persons and the judgment weight corresponding to the direct economic loss are \(w=[0.708 \ 0.231 \ 0.061] \), the evaluation matrix of each accident: \(B_1=[0.231 \ 0 \ 0.231 \ 0 \ 0.061] , B_2=[0.231 \ 0.708 \ 0.769 \ 0], B_3=[0.462 \ 0.061 \ 0.939] , B_4=[0.223 \ 0.185 \ 0.0708] \), determined according to the principle of maximum membership degree. The level of consequences of an accident, the law provides to some extent relevant experience for the qualitative analysis of other types of accidents.

(2) The fuzzy evaluation analyzes the weight of the factors that meet the consistency test from the microscopic point of view, and constructs the membership function for number of deaths, number of injured, direct economic loss according to the Regulations on Production Safety Accident Report and Investigation and Treatment. Then, through the weight calculation and the principle of maximum membership degree, the accident level is judged, which provides reference and reference for the final accident classification.

(3) Based on the number of casualties and economic losses, assist in determining the severity of the accident, make a certain contribution to determine the level of the accident, effectively reduce the subjectivity of human decision-making, and have the feasibility of the result of the accident division.

Acknowledgement:
I am very grateful to my tutor and classmates for their support and counseling for my thesis.

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