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Weights Computing Analysis of Multi-Criteria Evaluation for Buried Pipeline Failure

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Abstract. Multi-criteria evaluation (MCE) is the main method for failure analysis of buried pipeline. In multi-criteria evaluation, the effect of weights on results is obviously. In order to reveal the internal mechanism of the influence of weights, detailed analysis of criteria and order weights were carried out. According to six groups data of an application example for buried pipeline, influences of characteristics and ways of weights changing were investigated. Influences of criterion weights, order weights and synthetic weights were analyzed which revealed the relationship between weights and risk. This work has great significance to risk prediction of underground pipeline failure.

Introduction

For spatial distribution, multi-criteria evaluation is one of the main methods. Weights computing has been paid wide attention and applied in many engineering fields, such as buried pipeline failure [1-3]. Now weighted combination methods in GIS-based multi-criteria evaluation develop rapidly, especially weights computing, which is treated as aggregation of OWA operators [4-6].

Failure of underground pipeline is affected by many factors that can be treated as varying spatial data sequence, and show very strong spatial variability [7-9]. Also, the effect of weights on calculating results is obviously, which makes a sharp differ for evaluating results [10-11]. In this paper, detailed analysis of criteria and order weights in multi-criteria evaluation were carried out, and the internal mechanism of weights' influence was revealed. Characteristics and ways of weights changing were investigated, and the relationship between weight and risk was found.

MCE in Failure Prediction

Varying on spatial data sequence makes the array in any spatial point different. If R_i represents the risk (or evaluation result), it is written as,

$$R_i = \sum_{j=1}^{n}\left(\frac{u_j v_j}{\sum_{j=1}^{n} u_j v_j}\right) x_{ij} \tag{1}$$

In which, u_j is criteria weight of the factor j. v_j is order weight of the factor j. i represents spatial location number between 1 and m, j represents influence factors which changes from 1 to n. And the synthetic weight is written as,

$$w_s = \sum_{j=1}^{n}\left(\frac{u_j' v_j'}{\sum_{j=1}^{n} u_j' v_j'}\right) \tag{2}$$

In which, u_j' is criteria weight that represents the relative importance between factors, and does not relate to spatial location, v_j' is order weight that differs with spatial location.

Criteria weights can be calculated with a comparison matrix "A" that is determined by analytical hierarchy process (AHP) method. And order weights can be calculated as Eq. (3) which is called rank order method.

$$v_j = \frac{n - r_j + 1}{\sum_{l=1}^{n}(n - r_l + 1)} \quad (j, l = 1, 2, \cdots n) \tag{3}$$

In which, r_l is assigned as basis of rank class.

Analysis of Weights Computing

In order to analyze the influence of weights, six groups of data of an application example for buried pipeline can be shown as table 1.

Table 1 Normalized data of buried pipeline

No.	Buried depth	Fault throw	Site stability	Maximum	Minimum	Average
1	170	18	227	227	18	138.3
2	255	18	227	255	18	166.7
3	85	163	227	227	85	158.3
4	85	255	227	255	85	189
5	85	18	227	227	18	110
6	85	18	255	255	18	119.3

In table 1, the six groups of data have been normalized from 0 to 255. In this example, values represent safety degree, the greater the value, the less the risk. Influence of weights can be analyzed from three results data sequence, which are maximum, minimum, and average. The average equals to the same weight for all three factors with 1/3, the maximum means that weight 1 gives the maximum factor, and the minimum means the least numerical factor with weight 1 (see Fig. 1).

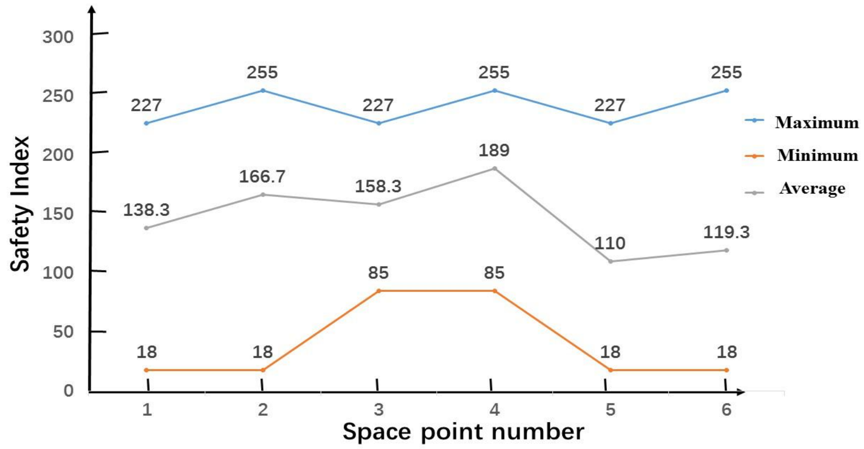

Fig. 1 Computing results of average

From Fig. 1, it can be found that the average results are the average of maximum and minimum. If selecting maximum safety index, highest decision-making risk will be faced.

Influence of Criteria Weights. Influence of criteria weights can be analyzed by weighted linear combination (WLC) method. The comparison matrix "A" is expressed as Eq. (4), and the criteria weights vector is shown as Eq. (5).

$$A = \begin{bmatrix} 1 & 2 & 6 \\ 1/2 & 1 & 3 \\ 1/6 & 1/3 & 1 \end{bmatrix} \tag{4}$$

$$w_c = [0.6 \quad 0.3 \quad 0.1]^T \tag{5}$$

With these criteria weights, the calculation results are listed in the table 2.

Table 2 Calculation with criteria weights

No.	Buried depth	Fault throw	Site stability	Result 1	Result 2
1	170	18	227	130.1	158.6
2	255	18	227	181.1	167.1
3	85	163	227	122.6	193.6
4	85	255	227	150.2	221.2
5	85	18	227	79.1	150.1
6	85	18	255	81.9	166.9

In table 2, when the buried depth is assigned weight 0.6, fault throw is assigned weight 0.3, and weight 0.1 for site stability, the calculating result is shown as result 1. But site stability is the maximum, and the least weight is assigned to it. If site stability is assigned weight 0.6, and buried depth is assigned weight 0.1. Results are shown as result 2. Then results can be plotted as Fig. 2.

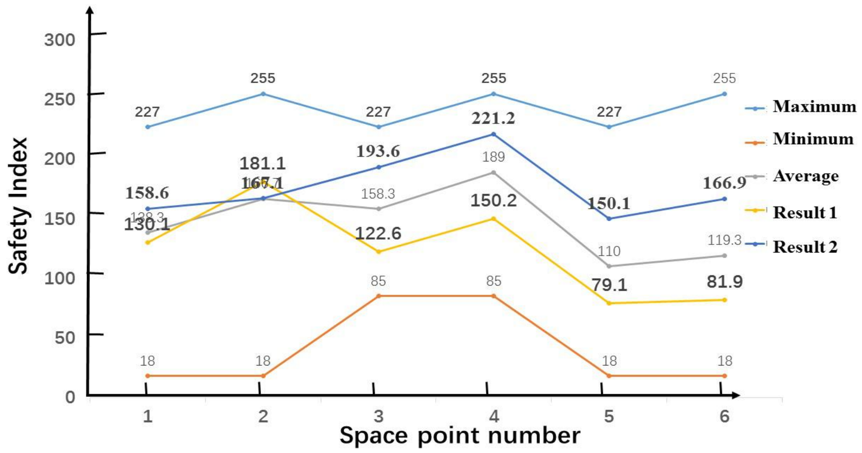

Fig. 2 Computing results with criteria weights

Fig. 2 shows that result 1 and 2 are around average, so WLC is a correction of average method.

Influence of Order Weights. Order weights can be obtained by Eq. (3), and results are 0.5, 0.33, and 0.17. Similarly to criteria weights, calculating results with order weights can be shown as Fig.3. Also, two sequence results are calculated as result 1 and 2. In result 1, the weight 0.5 is assigned to the maximum, and 0.17 to the minimum, conversely in result 2.

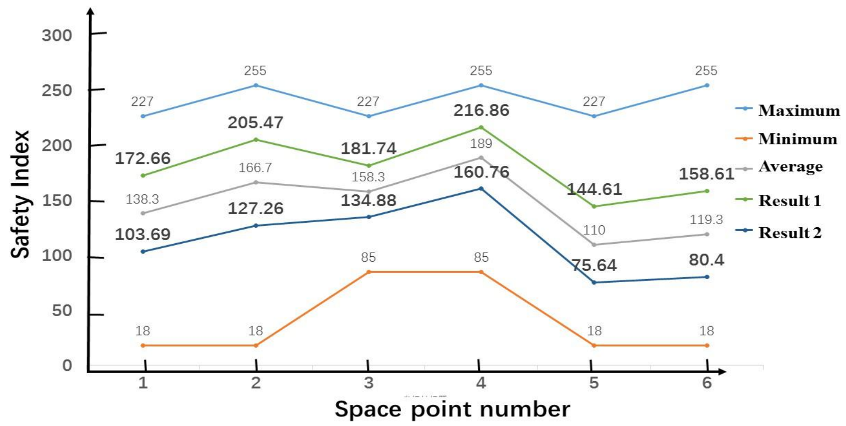

Fig. 3 Computing results with order weights

Fig. 3 shows that result 1 is located between maximum and average, and result 2 is located between minimum and average. It means that order weights give a new selection between maximum (minimum) and average.

Influence of synthetic Weights. According to Eq. (2), synthetic weights are calculated with criteria weights and order weights. But only weights in result 1 are considered which make the computing easy. Results are shown as table 3.

Table 3 Results with synthetic weights

No.	Data vector	Criteria weigts vecotr	Order weights vector	Synthetic weights vector	Results
1	170,18,227	0.6,0.3,0.1	0.33,0.17,0.5	0.66,0.17,0.17	153.85
2	255,18,227	0.6,0.3,0.1	0.5,0.17,0.33	0.78,0.13,0.09	221.67
3	85,163,227	0.6,0.3,0.1	0.17,0.33,0.5	0.41,0.39,0.2	143.82
4	85,255,227	0.6,0.3,0.1	0.17,0.5,0.33	0.36,0.53,0.11	190.72
5	85,18,227	0.6,0.3,0.1	0.33,0.17,0.5	0.66,0.17,0.17	97.75
6	85,18,255	0.6,0.3,0.1	0.33,0.17.0.5	0.66,0.17,0.17	102.51

It can be found that criteria weights are related with factors, and order weights are related with values of spatial points. Synthetic weights are combination of criteria and order weights, but not one to one correspondence. It means that the combinatorial order is different in different spatial location.

Results Analysis and Conclusion

To sum up, the internal mechanism of weights influence is that criteria weight is the correction of average, and order weight is a selection between average and maximum (or minimum), synthetic weight is the compensation of criteria weight with order weight. For any way of weights computing, it is a selection between maximum and minimum. With high safety index, it means high decision risk is chosen, and computing weights is only a selection of decision strategy. The results reveal that there is no better way, only better choice.

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