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# The study on the performance evaluation and influence factors of enterprise safety production based on combination weighting

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## ABSTRACT

To find the influence factors and evaluate the enterprise safety production, it constructed the index system of the safety production performance evaluation of enterprises, established the model of safety production performance evaluation of enterprises based on combination weighting method, and analyzed safety production performance and its influence factors of 20 manufacturing enterprises in Heilongjiang Province. The empirical results showed that factors such as the understanding of safety culture, the executive ability of safety behavior, people's physiological state, people's mental state and the establishment of safety monitoring organizations had the most important influence on enterprise safety production performance and the safety production performance of most enterprises of 20 was "normal". It provided the enterprises with some guiding significance when deal with safety production.

## KEYWORDS

Safety production performance; Influence factors; Safety behavior; Combination weighting; Evaluation.

# INTRODUCTION

Safety production is the basic guarantee for the survival and development of enterprises. Many enterprises has taken advanced foreign management methods and experience of safety production as reference actively[1],introduced and innovated safety production management style that suited for their own production condition, improved safety climate[2],building safety culture[2], and controlled hidden safety danger. But these measures and behaviors have not improve safety performance of enterprises.

It is generally believed that the workplace safety can be improved by safety climate[3-5]. The higher scores of safety climate organizations have, the better its safety production performance becomes[6,7]. The safety climate can predict safety related performance results such as accidents or injuries[4,8].

Some scholars considered the measurement of safety culture as part of the safety performance evaluation[3], but it should be pointed out that this assumption in the empirical research was not always able to pass the test[9]. Haleeta confirmed that the enterprise safety production performance can make great improvement without major changes in safety culture[10].

The study about the relationships among safety climate, safety culture and safety performance confirmed that the various influence factors were able to affect safety production performance through behaviors in end[11]. Some scholars used safety behavior of staff to evaluate safety performance directly[12].

Through combing the relevant research results, we have not found a perfect evaluation index system. Enterprises still need a set of scientific and effective safety production performance index system to evaluate the performance of enterprise safety production. Based on the situation above, it uses KPI (Key Performance Indicator, KPI) theory[13]to determine the safety performance evaluation index system of enterprises, and construct performance evaluation model based on combination weighting[14], to analyze important influence factors of safety production performance.

# THE CONSTRUCTION OF ENTERPRISE SAFETY PRODUCTION PERFORMANCE EVALUATION INDEX SYSTEM BASED ON KPI THEORY

KPI theory uses a few key indicators (20%) to evaluate the performance, and takes the key index as evaluation criteria, which can simplify the process of performance evaluation.

Enterprise's safety production performance evaluation of KPI is based on safety production strategic objectives. It refines the KPI dimensions of enterprise production safety performance by distinguishing the key elements used to ensure enterprise's safety production. It extracted 4 safety production performance evaluation index based on the theory of KPI. They are human factors ($X_1$), management system ($X_2$), equipment ($X_3$) and environmental conditions ($X_4$). Furthermore, the human factors ($X_1$) can be classified into safety culture understanding ($X_{11}$), safety behavior executive ability ($X_{12}$), human physiology state ($X_{13}$), and psychological state ($X_{14}$). The management system can be classified into the set of safety monitoring mechanism ($X_{21}$), inspection degree ($X_{22}$), safety propaganda and education ($X_{23}$), safety emergency treatment ($X_{24}$). The equipment index was decomposed of reasonable installation and control of equipment ($X_{31}$), equipment monitoring and maintenance ($X_{32}$). It classified the environmental conditions into temperature and humidity ($X_{41}$), noise and light of workplace ($X_{42}$)[15].

# THE CONSTRUCTION OF SAFETY PRODUCTION PERFORMANCE EVALUATION MODEL OF ENTERPRISE BASED ON COMBINATION WEIGHTING METHOD

The construction of safety production performance evaluation model based on combination weighting method comprises the following steps:

## Normalized index values

## To determine the weight by single method

**(a)The G2 method**

Determine the order relation with G2 method.

Give the least important index $x_k$.

Give the value of $d_j$ standing for the ratio of other index $x_j$ and the importance of index $x_k$.

The weighting of G2 Method (Formula 1)[16].

$$w_j = \frac{d_j}{\sum_{j=1}^{k} d_j} (i=1,2,...,n, j=1,2,...,m) \tag{1}$$

**(b)The Entropy Value Method[16](Guo-tai Chi,2012,pp.183-191)**

The $r_{ij}$ is the index proportion:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{2}$$

It made $e_j$ as the entropy value of $j$ the evaluation indicator :

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} r_{ij} \ln(r_{ij}) (i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{3}$$

It made $w_j$ as the weighting of $j$ the evaluation indicator :

$$w_j = \frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)} (i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{4}$$

**(c)The Maximization Deviation Method**

It took $w_j$ as weighting and used $H_{ij}(w)$ as the deviation of $i$ and other indicator's value, then constructed optimization deviation model:

$$\max H(w) = \sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1}^{n}\left|t_{ij}-t_{ik}\right| w_j (i=1,2,\ldots,n,\ j=1,2,\ldots,m)$$
$$s.t.\begin{cases} w_j \ge 0 \\ \sum_{j=1}^{m} w_j^2 = 1 \end{cases} (i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{5}$$

$$w_j = \frac{\sum_{i=1}^{n}\sum_{k=1}^{n}\left|t_{ij}-t_{ik}\right|}{\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1}^{n}\left|t_{ij}-t_{ik}\right|} (i=1,2,\ldots,n,\ j=1,2,\ldots,m, k=1,2,\ldots,n) \tag{6}$$

## Combination weighting

### (a)The calculation of combination weighting

It used G2 Method, Entropy Value Method, Maximization Deviation Method and combination coefficient $\alpha_c$ to calculate $w_c(c=1,2,3,4)$ , and combination weighting:

$$w = \sum_{c=1}^{s} \alpha_c w_c \tag{7}$$

### (b)How to determine $\alpha_c$

$$\min \sum_{i=1}^{n} l_i = \sum_{i=1}^{n} \sum_{j=1}^{.m} \sum_{c=1}^{s} \alpha_c w_j^c (1-x_{ij})(i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{8}$$

The $l_i$ was the generalized distance of weighted score of each evaluation object and the ideal point.

It utilized the Maximum Entropy Principle Jaynes (Formula9)to construct objective function (Formula10),(Formula11).

$$\max Z = -\sum_{c=1}^{s} \alpha_c \ln \alpha_c \tag{9}$$

$$\min \theta \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{c=1}^{s} \alpha_c w_j^c (1-x_{ij}) + (1-\theta) \sum_{c=1}^{s} \alpha_c \ln \alpha_c (i=1,2,\ldots,n,\ j=1,2,\ldots,m)$$

$$s.t. \sum_{c=1}^{s} \alpha_c = 1,\ x_c \ge 0 \tag{10}$$

$$\alpha_c = \frac{\exp\left\{-\left[1+\theta \sum_{i=1}^{n} \sum_{j=1}^{m} w_j^c (1-x_{ij}) / (1-\theta)\right]\right\}}{\sum_{c=1}^{s} \exp\left\{-\left[1+\theta \sum_{i=1}^{n} \sum_{j=1}^{m} w_j^c (1-x_{ij}) / (1-\theta)\right]\right\}} (i=1,2,\ldots,n,\ j=1,2,\ldots,m) \tag{11}$$

Safety performance evaluation of 20 enterprises:

$$Q = W^T \times X = (q_1, q_2, \cdots, q_n) \tag{12}$$

## THE EMPIRICAL ANALYSIS

### Data collection

It collected data from 20 manufacturing enterprises of Heilongjiang Province. The investigation objects were the senior managers who were familiar with the production process and safety management to make objective evaluation to their enterprises. The questionnaire adopted $Li\ker t7$ point scoring method.

### Data analysis

According to the process of G2 Method, Entropy Value Method and Maximization Deviation Method, it can calculate the weight of each corresponding method, then get the and the combination weighting, $\alpha_c = (0.2011, 0.2343, 0.2987, 0.2659)$ that was shown in TABLE1.

**TABLE 1. The weight of influence factors of safety production performance**

| The criterion layer | The index layer | G2 weighting | Entropy Value weighting | Maximization Deviation weighting | combination weighting |
|---|---|---|---|---|---|
| $X_1$ | $X_{11}$ | 0.1146 | 0.0925 | 0.0798 | 0.1033 |
| | $X_{12}$ | 0.1628 | 0.1124 | 0.1341 | 0.1364 |
| | $X_{13}$ | 0.1077 | 0.1347 | 0.0954 | 0.1157 |
| | $X_{14}$ | 0.1245 | 0.0654 | 0.0876 | 0.0907 |
| $X_2$ | $X_{21}$ | 0.0889 | 0.1087 | 0.1204 | 0.0976 |
| | $X_{22}$ | 0.0513 | 0.0991 | 0.0837 | 0.0788 |
| | $X_{23}$ | 0.0604 | 0.0578 | 0.0832 | 0.0659 |
| | $X_{24}$ | 0.0463 | 0.0922 | 0.0912 | 0.0720 |
| $X_3$ | $X_{31}$ | 0.0744 | 0.0453 | 0.0623 | 0.0638 |
| | $X_{32}$ | 0.0698 | 0.0578 | 0.0711 | 0.0677 |
| $X_4$ | $X_{41}$ | 0.0489 | 0.0679 | 0.0423 | 0.0535 |
| | $X_{42}$ | 0.0504 | 0.0662 | 0.0489 | 0.0546 |

The TABLE 1 shows that the safety behavior understanding ($X_{11}$), safety behavior executive ability ($X_{12}$), human physiology state ($X_{13}$), psychological state ($X_{14}$) and the set of safety monitoring mechanism ($X_{21}$) were the most important influence factors of safety production performance of enterprises.

## The safety production performance evaluation of enterprises

According to the combination weight calculation, it can evaluate the safety production performance of enterprise, which was shown in TABLE 2.

**TABLE 2 : The score of each criterion layer and comprehensive evaluation of safety production performance of 20 enterprises**

| | Comprehensive Evaluation | Criterion Layer $X_1$ | Criterion Layer $X_2$ | Criterion Layer $X_3$ | Criterion Layer $X_4$ |
|---|---|---|---|---|---|
| Enterprise1 | 0.6212 | 0.2514 | 0.1743 | 0.1024 | 0.0931 |
| Enterprise2 | 0.6861 | 0.1762 | 0.2061 | 0.1709 | 0.1329 |
| Enterprise3 | 0.4326 | 0.1357 | 0.1198 | 0.0932 | 0.0839 |
| Enterprise4 | 0.4578 | 0.1052 | 0.1265 | 0.1309 | 0.0952 |
| Enterprise5 | 0.3545 | 0.0836 | 0.0946 | 0.0787 | 0.0976 |
| Enterprise6 | 0.5262 | 0.1745 | 0.0971 | 0.0669 | 0.1877 |
| Enterprise7 | 0.5981 | 0.1105 | 0.0827 | 0.1736 | 0.2313 |
| Enterprise8 | 0.3531 | 0.0879 | 0.0615 | 0.1039 | 0.0998 |
| Enterprise9 | 0.6789 | 0.1848 | 0.1782 | 0.1834 | 0.1325 |
| Enterprise10 | 0.5178 | 0.1871 | 0.1579 | 0.0791 | 0.0937 |
| Enterprise11 | 0.6328 | 0.1716 | 0.0953 | 0.1850 | 0.1909 |
| Enterprise12 | 0.5478 | 0.1466 | 0.1676 | 0.0525 | 0.1811 |
| Enterprise13 | 0.5577 | 0.0818 | 0.1767 | 0.1693 | 0.1299 |
| Enterprise14 | 0.4421 | 0.0624 | 0.1176 | 0.1286 | 0.1335 |
| Enterprise15 | 0.3619 | 0.0951 | 0.0740 | 0.1046 | 0.0882 |
| Enterprise16 | 0.6543 | 0.1303 | 0.2158 | 0.1163 | 0.1919 |
| Enterprise17 | 0.4346 | 0.0765 | 0.1595 | 0.1141 | 0.0845 |
| Enterprise18 | 0.5895 | 0.1156 | 0.1477 | 0.1858 | 0.1404 |
| Enterprise19 | 0.5037 | 0.0974 | 0.1014 | 0.1457 | 0.1592 |
| Enterprise20 | 0.5598 | 0.1755 | 0.1332 | 0.1534 | 0.0977 |

## CONCLUSION

In this paper, it analyzed various factors affecting safety production performance of Chinese enterprises based on the theory of KPI to construct a safety production performance evaluation index system of enterprises, which included 4 dimensions: human factors, management system, equipment and environmental conditions. Then it introduced the combination weighting and Jaynes Maximum Entropy Principle into the safety production performance evaluation, took 20 manufacturing enterprises as the research objects, analyzing the influence factors of safety production empirically. The empirical results showed that the method had scientific reasons and operability.

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