# Classification method for safety status of industrial enterprise based on BP neural network

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## ABSTRACT

For the purpose of exploring the classification method for safety status of industrial enterprise, a safety index system was constructed and a model based on back propagation (BP) neural network was also built and applied. The safety index system includes 5 factors and 20 properties. Industrial enterprise can be classified into 4 levels: D, C, B and A, where A is the highest level. 14 training samples and 6 test samples was chosen to train and test the BP neural network until the results achieved the high accuracy, and then the model was used in practical application. The results show that the safety index system is comprehensive and scientific, and the model based on BP neural network is effective enough to reasonably classify safety status of industrial enterprise. This method can be helpful for safety management of government and enterprises themselves.

**Keywords:** Safety index system, BP neural network, classification model

## 1. INTRODUCTION

With the rapid development of industrialisation, safety has been an important issue not only because of an increase in public awareness but also due to the higher standard of occupational health and safety. The dangers in industrial processes and the weakness in safety management can cause incident which brings loss of lives and properties. Avoiding this serious threat for economic development has been a target for government and industrial enterprises[1]. Thanks to the recent development of safety science and technology, several studies on safety in industry are carried out by government, enterprises and academic organizations[2]. An amount of safety techniques, such as regulation research, Work Safety Standardisation, Occupational Health and Safety Management System certification and Safety Culture Construction, are widely adopted in different areas. It is meaningful for enterprise to discover the weakness of safety status and refine improvements. It also provides recommendations for government supervision focusing on different enterprises which are evaluated and ranked.

Due to the diversity of safety elements in the industry, it is difficult to cover all of them. Several important aspects are taken into consideration which form an index system in this paper, based on that evaluation and classification can be undertaken. The BP neural network is selected in building evaluation and classification model, which is mature enough to be applied. The input signal transmits forward in this multi-layer feedforward neural network, and information is processing layer by layer until the output. When it cannot achieve the expected output, the error is propagated back to adjust the weights and thresholds, and make the result constantly approach the expected output[3-4].

## 2. SAFETY INDEX SYSTEM

After analysing the factors that are considered in relevant research in several areas[5-12], a safety index system is constructed which contains 5 factors: Safety Management, Safety Condition, Incident Emergency, Safety Indicator and Safety Advance. 20 properties are considered to support the factors. The safety index system is shown in Table 1, where $F_i$ refers to the factor, $P_j$ refers to the property.

## 3. CLASSIFICATION MODEL

### 3.1 Classification

Based on the safety index system, the safety status of industrial enterprise can be classified into 4 levels: D, C, B and A,

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where A is the highest level.

Table 1. Safety index system of industrial enterprise.

| Factors | Properties | Remarks |
|---|---|---|
| $F_1$ Safety Management | $P_1$ Safety Organisation | Safety management leadership, management organisation and staff |
| | $P_2$ Safety Responsibility | Responsibility and task |
| | $P_3$ Safety Rule | Regulation, regime and operating instruction |
| | $P_4$ Safety Culture | Propaganda, education and training |
| | $P_5$ Dual Prevention | Risk control and accident potential rectification |
| | $P_6$ Project Management | Engineering construction management, safety facility management, contractor management |
| | $P_7$ Resource Support | Human resource, funding, technology, equipment and material |
| | $P_8$ Safety Technique | Work Safety Standardisation, Occupational Health and Safety Management System certification, Safety Culture, safety informatisation and safety conference |
| | $P_9$ Safety Inspection | Supervision and examination |
| $F_2$ Safety Condition | $P_{10}$ Facility | Distribution, construction, equipment and facilities, fire fighting facilities, special equipment |
| | $P_{11}$ Operation | Process, personal protection, production work, maintenance work, dangerous work |
| | $P_{12}$ Circumstance | Outer and inner circumstance, emergency lighting, exit, platform, stair, warning sign |
| | $P_{13}$ Material | Raw material, auxiliary material, product |
| $F_3$ Incident Emergency | $P_{14}$ Incident Management | Investigation and treatment |
| | $P_{15}$ Emergency Preparedness | Emergency organisation and personnel, emergency response plan, emergency supply and equipment, emergency exercise |
| | $P_{16}$ Emergency Treatment | Report, rescue and treatment |
| $F_4$ Safety Indicator | $P_{17}$ Absolute Indicator | Number of incidents, fatal accidents, deaths, injury, working hour loss, economic loss |
| | $P_{18}$ Relative Indicator | Rate of incident, death, injury, working hours loss, economic loss |
| | $P_{19}$ Reward and Punishment | |
| $F_5$ Safety Advance | $P_{20}$ Improvement | Reinforcement and promotion |

### 3.2 Data collection

Considering enterprises on different levels, 20 samples are selected as training and test samples. Expert scoring method is used to score on 20 properties for each sample. The flow chart of expert scoring is expressed in Figure 1.

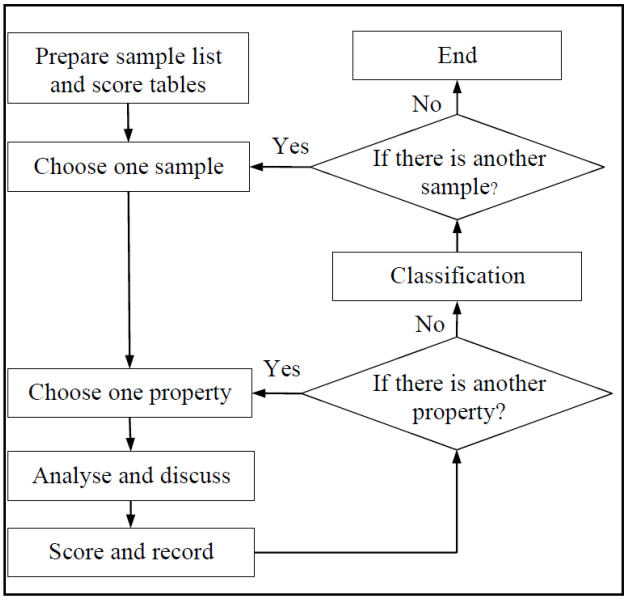


Figure 1. Procedures of expert scoring.

Five experienced experts from government, enterprises and institution are invited and score following the scoring rules shown in Table 2. A final classification conclusion is also drawn for each sample. 20 sets of data are recorded. The number of the samples on D, C, B and A level are respectively 2, 3, 3 and 2.

Table 2. The scoring rules for expert scoring.

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Poor, weak | Fair, pass | Good, merit | Excellent, distinction |

### 3.3 BP neural network design

A BP neural network which structure contains three-layer: input-layer, hidden-layer and output-layer, is suitable enough for model building and data computation in this paper. According to the number of properties and classification levels, the number of nodes in input-layer is 20, and the number of nodes in output-layer is 4. The number of nodes in hidden-layer is intended to be 11 by calculation based on the empirical equation below.

$$s = \sqrt{0.43mn + 0.12n^2 + 2.54m + 0.77n + 0.35} + 0.51 \quad (1)$$

where $n$, $m$ and $s$ are respectively the number of nodes in input-layer, output-layer and hidden-layer.

Thus, a BP neural network is designed which structure is "20-11-4". The topological graph is drawn in Figure 2. where $x_i$ refers to input data, $y_i$ refers to output data. $IN_i$ $HN_i$ and $ON_i$ respectively refers to node in input-layer, hidden-layer and output-layer.

### 3.4 Network building, training and test

Input data are 20 sets of numbers range from 0 to 4. Output data are 20 sets of classification results, which are all transformed to [1 0 0 0], [0 1 0 0], [0 0 1 0] and [0 0 0 1] that separately refer to the level of D, C, B and A. The number of input data and output data are separated as shown in Table 3.

Several codes are written to build a BP neural network in MATLAB®. The maximum number of training times is set to 1000, the training error is set to 0.0001, the learning rate is set to 0.01. Training data are input in the network, then the program is run until it reaches the set parameters. Subsequently, this network is tested by inputting the test data. In order to make a comparison between test results and expected outputs, a plot is drawn as shown in Figure 3.

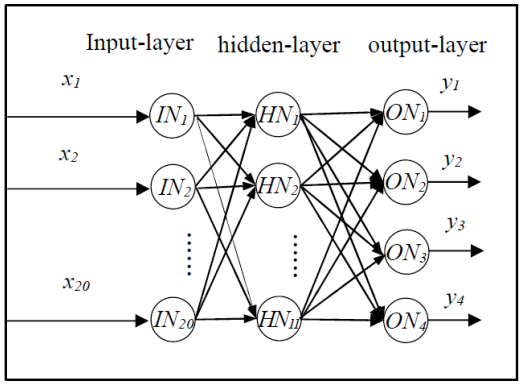


Figure 2. Topological graph of the BP neural network.

Table 3. Training and test data separation.

| | D | C | B | A |
|---|---|---|---|---|
| Outputs | [1 0 0 0] | [0 1 0 0] | [0 0 1 0] | [0 0 0 1] |
| Training Data | 1 | 2 | 2 | 1 |
| Test Data | 1 | 1 | 1 | 1 |

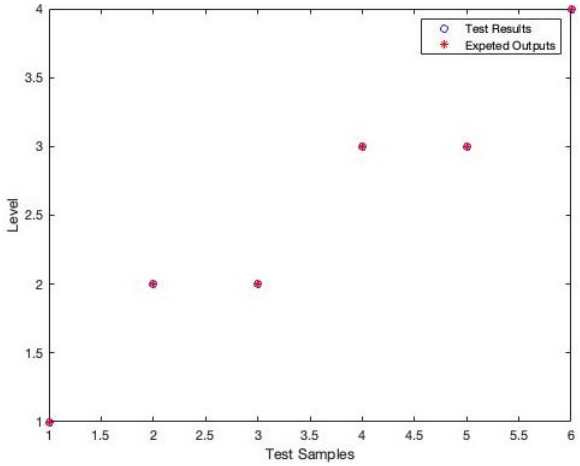


Figure 3. Comparison between test results and expected output.

The round symbols refer to the test results and the star symbols refer to the expected outputs. Abscissa refers to the number of test samples, and the ordinate refers to level of safety status D (1), C (2), B (3) and A (4). From the plot, it can be seen that the round symbols exactly coincide the star symbols, which means that test results give a good fit to expected outputs and the accuracy rate is nearly 100%. Therefore, it is proved that this BP neural network is accurate enough to be applied for classification of safety status in industry.

## 4. APPLICATION

This method is applied to help the local government to evaluate and classify safety status of enterprises. Two of them, H and J, are chosen to be classified using the classification model based on BP neural network which is well trained and tested.

Five experienced experts from government, enterprises and institution are invited and score following the scoring rules in the same way. The average of five scores is considered as the final score for each property. All of the scores are shown in Table 4 below.

Table 4. Input data of application samples.

| Factors | Properties | Enterprise H | Enterprise J |
|---|---|---|---|
| $F_1$ | $P_1$ | 2.4 | 3.6 |
| | $P_2$ | 2.2 | 3.2 |
| | $P_3$ | 1.0 | 2.8 |
| | $P_4$ | 2.2 | 3.4 |
| | $P_5$ | 1.8 | 3.2 |
| | $P_6$ | 2.2 | 3.2 |
| | $P_7$ | 2.0 | 3.2 |
| | $P_8$ | 1.4 | 3.3 |
| | $P_9$ | 2.0 | 3.2 |
| $F_2$ | $P_{10}$ | 2.2 | 2.8 |
| | $P_{11}$ | 2.0 | 3.2 |
| | $P_{12}$ | 2.4 | 2.8 |
| | $P_{13}$ | 2.0 | 3.0 |
| $F_3$ | $P_{14}$ | 1.8 | 2.6 |
| | $P_{15}$ | 2.6 | 3.4 |
| | $P_{16}$ | 2.0 | 3.2 |
| $F_4$ | $P_{17}$ | 2.4 | 2.6 |
| | $P_{18}$ | 2.6 | 2.6 |
| | $P_{19}$ | 2.2 | 3.2 |
| $F_5$ | $P_{20}$ | 2.0 | 3.0 |

After inputting the data and running the model program, the results show [0.375 1.0529 -0.1871 -0.0243] and [0.1469 0.23345 -0.0566 0.7581]. The values most approaching to 1 in two samples appear in the second and forth position, thus they can be approximately called [0 1 0 0] and [0 0 0 1]. That means enterprise H is on C level and enterprise J is on A level. This results well satisfy the expectation of experts. A decision is finally made by the local government that safety inspection will be undertaken once a month for enterprise H and twice a year for enterprise J.

## 5. CONCLUSIONS

The scope of this research is to explore a scientific classification method for safety status of industrial enterprise. A safety index system contains numerous properties is constructed and makes a contribution for model building. Enterprises can be classified into 4 levels by using the classification model based on BP neural network. It is proved that this model can be accurately applied in industry. This classification method will be helpful for safety management of government and enterprises themselves.

## ACKNOWLEDGMENTS

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