# Traffic Safety Evaluation in the Port Roadway Based on BP Neural Network

**Li-shan Sun, Wei Luo, Wei Zeng, Cong-ying Qiu and Li Cui**

**Abstract** On the basis of comprehensive analysis of traffic safety evaluation studies abroad, this paper presented the evaluation index system composed of four areas, such as people, traffic flow characteristics, traffic environment, and traffic management, consisting of a total of 15 indexes for special situation and problems in port road traffic safety. Each index has definite index classification criteria, evaluation requirements, and investigation methods. This paper also built evaluation model based on BP neural network and analyzed its calculation method in detail. This method has a guiding role for the management and decision levels of the port road traffic management department.

**Keywords** BP neural network · Port road · Safety evaluation · Traffic safety

## 1 Introduction

In recent years, with the rapid economic growth and with the increasing number of motor vehicle ownership, the number of accidents and deaths has been growing. Related to traffic safety, researchers conducted extensive research, and it has made some progress. But in the current feasibility study of highway and the preliminary design stage, the evaluation and optimization of overall road safety are still relatively lacking. In particular, research work in the port area and other aspects of road accidents is not an in-depth investigation. A typical set of port traffic brings about

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adverse phenomenon, such as overload, overloaded weight, and large traffic volume, because of its special functions. The traffic environment is harsh.

Based on the above background, for the special status and existing problems of port road traffic, this paper established a comprehensive index system for special port road traffic conditions, constructed the evaluation model based on BP neural network, and introduced the realization of the model. This method can play an important role in improving the traffic administrative department of the management and decision-making level.

## 2 Literature Review

Evaluation of road traffic safety is the evaluation of a particular area, route, road, or place (section), which can provide an important basis for the objective analysis of road safety conditions (Chen et al. 2008). It analyzes the road traffic safety situation, development process, and trends and then estimates the level of road safety in traffic safety evaluation. Traffic safety evaluation provides an effective basis for studying traffic safety management systems and traffic safety technology. It can improve traffic safety measures and planning and management level. It also can effectively control the growth trend of traffic accidents and reduce the loss of traffic accidents.

The main method of traffic safety evaluation is the probability and statistics and incremental analysis abroad. Analysis of these methods is too simple and not taking into account other factors from the root. It is difficult to make an accurate assessment, and therefore, it does not have the versatility. Hakkert et al. (1996) used the CART method to analyze the security level for intercity main road. But the road conditions are variable and limited. So their research only has a certain representative. USA scholar Perkins (Safety Campaign Annual Seminar 1999) put forward the traffic conflict technique (TCT), but it is fairly difficult to realize. Because it requires auxiliary technique, and the observation of traffic conflict is complex.

Scholars at home have studied much more about traffic safety, but most of the studies concentrated in these two areas too. Zhang (1998) proposed a Chinese TCT, but this method is more complicated to operate. Qing (2002) used the grade coefficient method system to study the state of road safety systematically. This method is simple, practical, and easy to accept by road base management personnel. But it also has shortcomings, which are lack of accuracy and a practical improvement on application. Zufeng (2008) set up a reasonable evaluation index system which consists of four aspects: people, vehicles, road, and environment. But the human factors are fairly heavy when scaling the ratings.

The artificial neural network has some similar characteristics with human brain neural networks, such as self-learning, self-organization, nonlinear dynamic processing, distributed knowledge storage, and memory. It provides a powerful tool for the study and to deal with uncertainty phenomenon (Yang et al. 2005). Because of its characteristics, neural network has been applied to the traffic field in recent years. Pan et al. (2005) put forward a comprehensive evaluation method based on

the gray cluster theory and neutral network technology. But the precision of the model still have much room for improvement. Chen (2006) has used BP neural network method on Beijing city road to traffic safety level evaluation and got a higher forecasting accuracy. According to the actuality of freeway traffic safety, Li and Wang (2010) have proposed the model of BP neural network. Application of BP neural network in traffic field gradually perfected.

Many factors influence the road traffic safety in port. The relationship is complex, the noisy data is huge, and factors are difficult to determine, in line with the characteristics of neural networks. Therefore, it is entirely scientific to use artificial neural network study traffic safety evaluation in port area.

## 3 Establish Traffic Safety Evaluation Model in the Port Roadway Based on BP Neural Network

Based on determining the port complex traffic state the evaluation system, it confirms object vector and sample data. Then, it conducts the BP neural network algorithm and the specific evaluation process graph model as shown in Fig. 1.

### *3.1 The Establishment of Index System*

There are many impacts on traffic safety indicators. It is necessary to consider the characteristics of indicators, logical relationships between indicators, targets, and quantization, and other issues. Only in this way, it can put amount of integrated indicators together. Otherwise, it will lose its reasonableness and the true value of traffic safety comprehensive evaluation (Weimin and Yi 1999).

From the harbor complex state highway starting, traffic safety evaluation system is divided into four main factors: characteristic aspects of the driver, traffic flow characteristics, and traffic management.

Drivers' characteristics factors. The human factor is the most important cause to induce road traffic accidents. As subject of traffic behavior, human is one of the most important factors in the road traffic accident cause. The first element of human factors is motor vehicle drivers. Their professional skill, driving experience, safety awareness, and drunk driving are closely related to the occurrence of traffic accidents. According to the survey on the cause of the accident in some of the major countries, the average proportion of the driver factors is 70.8 %. In addition, non-motorized vehicle drivers and pedestrians who lack awareness of traffic safety, poor in self-awareness, and ignore the traffic rules cause many traffic accidents too. Therefore, the decisive factor to improve traffic safety and reduce traffic accidents is improving the people's safety awareness and ameliorating safety behavior.

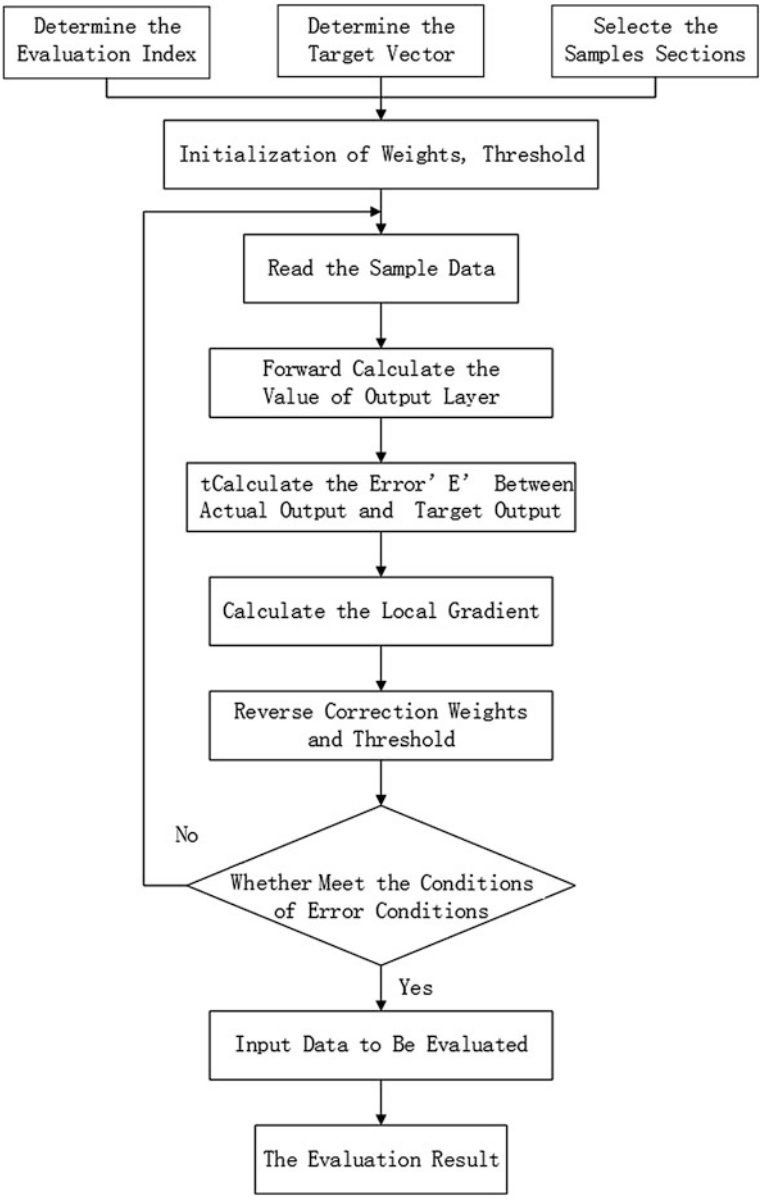


**Fig. 1** The process of BP neural network model

Traffic flow characteristics factors. Traffic flow factors include traffic volume, speed and density, and extracting metrics, such as saturation, design speed, and average speed. Different types of vehicles are running on the road. Their running

state is having different changes not only with the traffic environment and driver's characteristics, but also with the characteristics of road.

Traffic environmental factors. Environmental factors include road alignment of flat, vertical, and horizontal, traffic signs, safety facilities, and weather. There are no complete traffic signs and safety facilities in some areas. Thus, it causes the driver lax security awareness. So it causes more serious accidents. Noise and weather also have an important impact on traffic safety, for example, in the rain, snow, fog, and other inclement weather conditions, and driving safety factor will come down.

Traffic safety management factors. Traffic management systems include monitoring and management. Traffic management and monitoring system use the intelligent transportation systems (ITS) in traffic management system to establish integrated transportation management system, which can round play a role, real-time, accurate, and efficient. Research shows that the implementation of ITS can make the road capacity increased by 2–3 times. When the vehicles travel on intelligent roads, the traffic accidents can be reduced exponentially.

To sum up, in line with the scientific objectivity, availability, completeness, and feasibility, the evaluation index system is established, as shown in Table 1. The evaluation index system has four categories, fifteen indicators. Ten indicators are quantitative index. And five indicators are qualitative indexes (P12, P32, P33, P41, and P42). Each indicator is determined based on the index grading, evaluation requirements, and survey methods, and divided into excellent, good, medium, and poor, in the 4 grades.

**Table 1** Traffic safety evaluation index system of port road

| First-grade indexes | | Second-grade indexes | |
|---|---|---|---|
| Names of indexes | Coding | Names of indexes | Coding |
| Drivers | P1 | The proportion of drivers who have less than 35 years of driving experience | P11 |
| | | Safety awareness of drivers | P12 |
| Traffic flow | P2 | Saturation | P21 |
| | | The size of the proportion of vehicle traffic | P22 |
| | | Design speed | P23 |
| | | Average speed | P24 |
| | | The average speed difference between carts and trolley | P25 |
| | | Headway | P26 |
| | | The ratio of lane change | P27 |
| Traffic environment | P3 | The bad weather days in a year | P31 |
| | | Safety induction facility | P32 |
| | | Safety protection facilities | P33 |
| | | The alignment of flat, horizontal, and vertical | P34 |
| Traffic safety management | P4 | Monitoring system | P41 |
| | | Management | P42 |

## 3.2 The Model Construction of the Evaluation Index System of BP Network

Based on the evaluation index system, the construction of BP network input layer is 15 nodes corresponding to the 15 indexes. The corresponding index which the qualitative index value converted into quantitative index as input data into the BP network to calculate.

### 3.2.1 The Number of Hidden Nodes in Middle Layer

In the engineering case, it usually uses the following formula to determine the intermediate layers (Zhang 1993):

$$n_1 = \sqrt{n+m} + a \tag{1}$$

where
$n_1$ is the node number of hidden layers;
$n$ is the node number of input layer;
$m$ is the node number of output layer; and
$a$ is constant between 1 and 10.

In this paper, it uses the above formula to calculate the initial value of hidden layer nodes. On this basis, it uses the test method. The procedure is as follows: It continuously changes the hidden layer node in the training process, through the evaluation and comparison of the network training and test errors, training step, network structure, and other standards in different number of hidden nodes to select the optimal number of hidden nodes. After the spreadsheet, finally, it selected twenty-two nodes.

### 3.2.2 The Division of Evaluation Grade

This study will divide the evaluate level into 4 levels. The expected output value is shown in Table 2.

Corresponding to the four grades, the output layer has four nodes. It constructs a "15-22-4"—three layered BP network as the network model evaluation system. After calculating the output layer data, the results are compared with the expected output value. Then, there got the specific evaluation grade, as shown in Fig. 2.

**Table 2** The division of evaluation grade

| Security classification | Desired output |
|---|---|
| Very safety | 0.9, 0.1, 0.1, 0.1 |
| Relatively safety | 0.1, 0.9, 0.1, 0.1 |
| General safety | 0.1, 0.1, 0.9, 0.1 |
| Unsafety | 0.1, 0.1, 0.1, 0.9 |

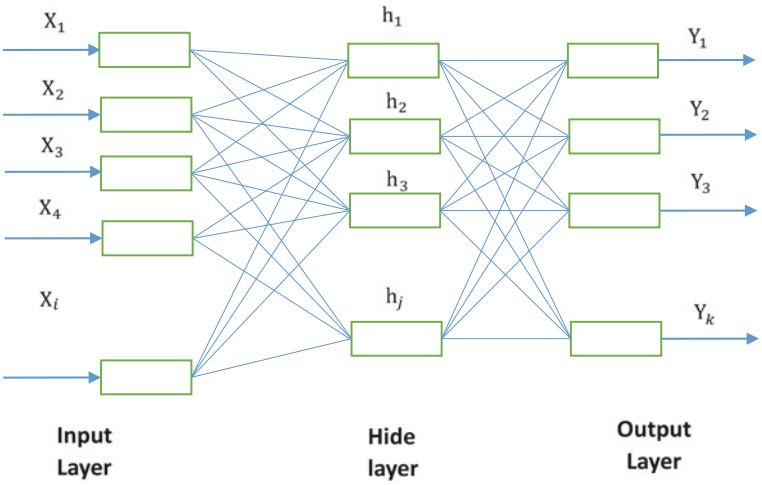


**Fig. 2** The schematic diagram of *three layers* of BP neural network model

## 4 The Specific Realization of the BP Neural Network Model

### *4.1 Setting Network Parameters*

The training parameters are an important index to determine the network performance, including the initialization of weights and thresholds, net.trainParam parameters (Liu et al. 2010). The system will automatically initialize the given weights and thresholds. And the specific net.trainParam parameter settings are shown in Table 3.

### *4.2 The Training Model*

When setting the network parameter, it can enter the network sample data files and the weight matrix, beginning to training network.

In the process of realizing the traffic safety evaluation method of neural network, the key is determining the value of input and output in sample model. This study

**Table 3** The settings of evaluation network parameter

| Code of parameters | Meanings of parameters | Setting value |
|---|---|---|
| net.trainParam.show = 1 | Display interval in training | 1 |
| net.trainParam.time = 500 | Time allowed in training | 500 |
| net.trainParam.lr = 0.3 | Learning step | 0.3 |
| net.trainParam.mc = 0.95 | Momentum parameter | 0.95 |
| net.trainParam.epochs = 1,000 | The maximum number of training | 1,000 |
| net.trainParam.goal = 0.001 | The minimum mean square error | 0.001 |

selected five typical port road data as the sample data. The results in network training are as shown in Figs. 3 and 4.

As shown in Fig. 3, the training results and expected output value reached 0.89631. It is good fitting. As shown in Fig. 4, the neural network comes to complete the training when iterates 901 times. The error reached its target goal. Therefore, the training effect is good, and it accepts the neural network model.

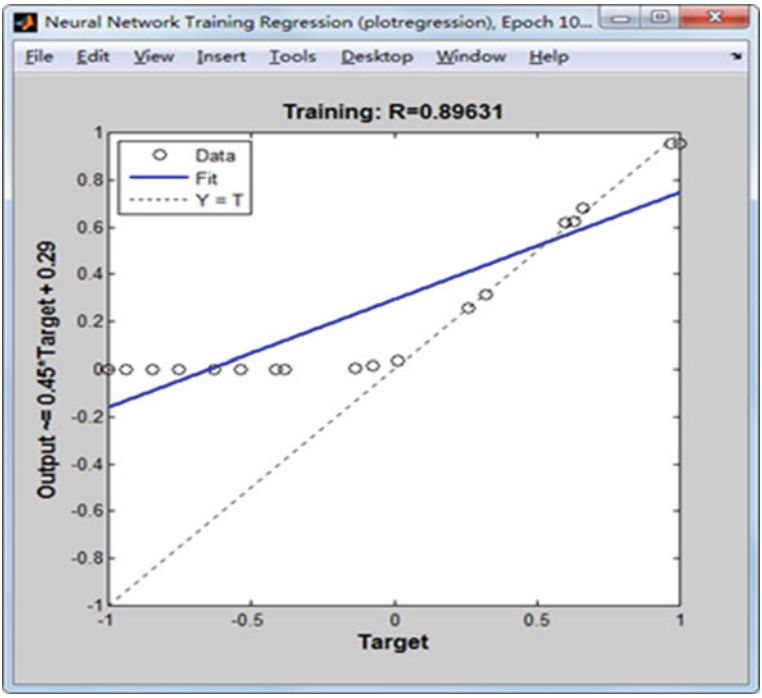


**Fig. 3** The results of training network

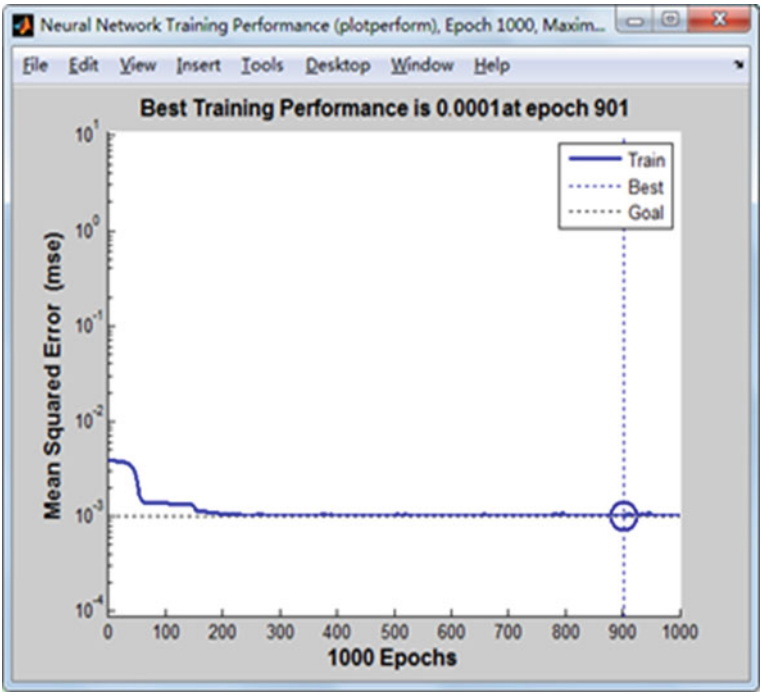


**Fig. 4** The error log curve in the process of network training

## *4.3 Example Analysis*

As development of a key city, The Binhai New District of Tianjin highway transportation development is extremely rapid.

With the rapid development of Binhai New District and a large number of motor vehicle soared, it aggravates the structural contradictions between growth of motor vehicle and private facilities lag, causing the seaside Avenue Road in Binhai New District' traffic conditions are more complex. Combined traffic environment research, questionnaires of traffic participants, and other forms, it conducted an traffic investigation analysis for the seaside Avenue Road. The evaluation index values are shown in Table 4.

Put the evaluation index values obtained from investigation into the BP neural network evaluation model that has been built. The result is "$a$ = (0.003, 0.0397, 0.0790, 0.9931)". From the evaluation results, the fourth data are the maximum—0.9931, closing to 0.9. The other data are in the vicinity of 0.1. The evaluation result is convergent, so it can determine that the freeway traffic safety situation is not safe. According to the result of the evaluation, the traffic environment of seaside Avenue Road is not good, needing for traffic optimization and strengthening traffic safety management.

**Table 4** The settings of evaluation network parameter

| Names of index | Score |
|---|---|
| The proportion of drivers who have less than 35 years of driving experience (P11) | 81 |
| Safety awareness of drivers (P12) | 79 |
| Saturation (P21) | 52 |
| The size of the proportion of vehicle traffic (P22) | 75 |
| Design speed (P23) | 120 |
| Average speed (P24) | 70 |
| The average speed difference between carts and trolley (P25) | 29 |
| Headway (P26) | 9 |
| The ratio of lane change (P27) | 53 |
| The bad weather days in a year (P31) | 49 |
| Safety induction facility (P32) | 82 |
| Safety protection facilities (P33) | 81 |
| The alignment of flat, horizontal, and vertical (P34) | 72 |
| Monitoring system (P41) | 85 |
| Management (P42) | 83 |

## 5 Conclusion

This paper presented the evaluation index system suitable for port special traffic conditions. On this basis, the port road safety evaluation model based on BP neural network was designed and developed. After the model was applied to the seaside Avenue Road, the conclusion is that the seaside Avenue Road is in unsafe traffic condition. BP neural network safety evaluation model proposes a new way for solving port safety evaluation of the uncertainty and the dynamic complexity and also avoids the difficulties encountered as the establishment of a complex mathematical model to describe the nonlinear relationship.

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