Study on early warning model of construction safety accident based on support vector machine

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ABSTRACT: In view of the problem that the occurrence rate of construction safety accidents is higher, questionnaires, on-site interviews and other research methods had been applied to analyze the present situation of construction safety production management in our country. Summary up the main factors that lead to the occurrence of construction safety accidents, like human factor, material factor, environment factor and management factor. Construction safety accident early warning model had been established based on support vector machine. Then analyze the practical feasibility of early warning model. It not only provides a new method for the accurate early warning of safety accidents, but also provides a theoretical support for the prevention of safety accidents.

INTRODUCION

With the rapid development of economic construction in our country, the construction industry is growing by leaps and bounds. In recent years, the construction safety accidents have occurred frequently. And the number of construction accidents is rising each year, as well as the number of deaths. The Chinese government leaders have always attached great importance to productive safety problems. The relevant government departments also took a lot of countermeasures and measures. It caused us deep reflection by current present condition of production safety management system in our country because the strategies and measures did not control the frequent occurrence of safety accidents effectively. Construction safety accidents occur frequently has become an important negative factor that it restricted the sustainable development of construction industry. How to effectively prevent the occurrence of safety accidents, avoid personal injury and economic losses has become the important topic of the construction industry.

China's construction industry has been booming since reform and opening up. The construction industry competition is increasingly fierce as the overall development of market economy[1~2]. China's construction industry ushered in the development of opportunities, but also needed to face challenges and shocks especially after China's accession to the WTO. In recent years, China's construction industry is in a sustained increase in the proportion of the national economy output and has made important contribution to economic development[3]. In 2013, the national construction industry output value was ￥159313 billion, increasing 16.1% over 2012. The national infrastructure investment was ￥ 71695 billion, an increase of 21.2% over the previous year. The total new construction project investment was ￥ 864646 billion, an increase of 16.2% over the previous year. All new projects investment was ￥357815 billion, an increase of 14.2% over the previous year. According to the national bureau of statistics data from 2004 to 2012, the number of employees of construction industry increased to 42672 thousand in 2012. The total output of

construction industry increased to 137217.86 billion in 2012. The proportion of construction industry in the GDP increased to 6.84% in 2012. As the growth of the national economy steady, the construction industry has developed into the important pillar industry of the national economy. However, labor intensive and great investment of construction projects lead to serious casualties and property losses[4~5]. The direct economic losses caused by accidents were more than billions and tens of thousands of people died in the accident every year. The current safety present situation in construction industry restricted the sustainable development of the industry severely[6].

CONSTRUCTION SAFETY SITUATION AND ACCIDENT CAUSE ANALYSIS

accident number and death tolls

In this paper, the construction accidents happened in residence building construction and municipal engineering construction from 2004 to 2012 has been carried on the statistical analysis[7]. The annual number of construction accidents was shown in figure 1. The annual number of death tolls was as shown in figure 2. The tendency chart between accident numbers and death tolls was shown in figure 3.

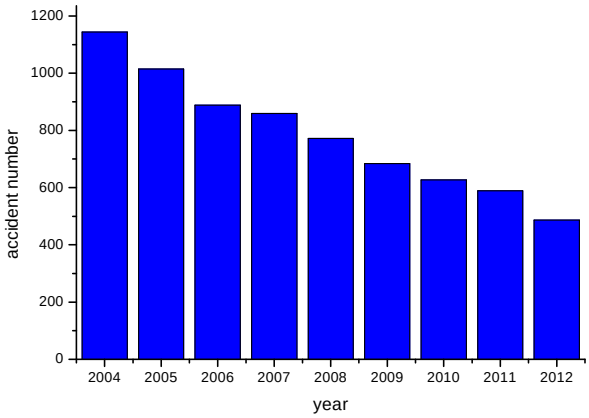

Fig.1 Annual number of construction accidents from 2004 to 2012

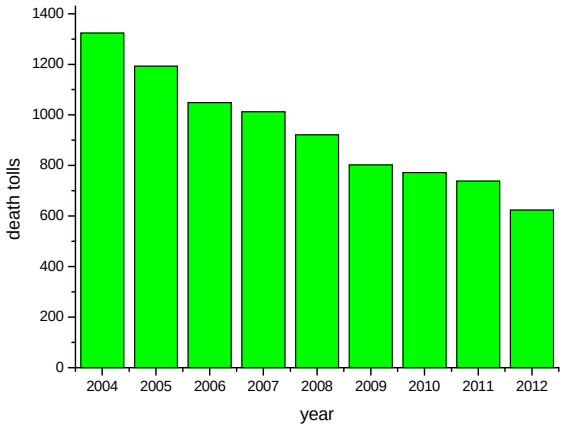

Fig.2 Annual number of death tolls from 2004 to 2012

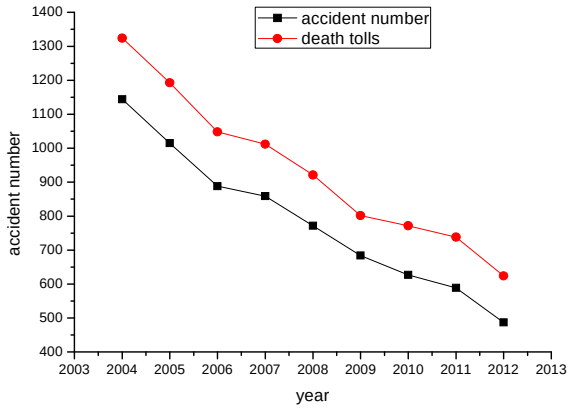

Fig. 3 The tendency chart between accident numbers with death tolls from 2004 to 2012

From figure 1, figure 2 and figure 3, the annual number of construction accidents and death tolls showed a downward trend form 2004 to 2012. There are a lot of laws and regulations to standardize production activities in construction safety, especially since the implementation of the construction safety production management ordinance. In the vigorously promotion of the competent department of the government at all levels and under the mandatory requirements, construction safety situation was improved obviously. Besides, the number of accidents and deaths is fall because construction enterprises began to attach great importance to the safety management[8~9].

Although the annual number of construction accidents and death tolls in our country from 2004 to 2012 is on the decline, the absolute occurrence of accidents and deaths are still not low. So, our building construction safety situation is still grim.

2.2 *The main accident types*

The main accident types can be listed based on the statistical analysis of the Chinese construction accident from 2004 to 2012, as shown in table 1. The distribution diagram of main accidents from 2004 to 2012 was shown in figure 4.

Table1 The main accident types of construction accident from 2004 to 2012

year / accident type	2004	2005	2006	2007	2008	2009	2010	2011	2012	mean
Fall injury（%）	53.1	45.52	41.03	45.5	52.03	51.9	47.37	53.31	52.77	49.17
Collapse injury（%）	14.43	18.61	20.61	20.36	13.86	13.74	14.83	14.6	13.76	16.09
object strike injury（%）	10.57	11.82	12.79	11.56	11.37	12.28	16.75	12.05	12.11	12.37
lifting injury（%）	3.1	5.53	8.78	6.62	8.76	6.43	7.02	8.32	10.27	7.2
electric shock（%）	7.18	6.54	6.2	6.42	5.62	4.09	4.63	5.09	2.05	5.31
Other kinds（%）	11.62	11.98	10.59	9.54	8.36	11.56	9.4	6.63	9.04	9.86

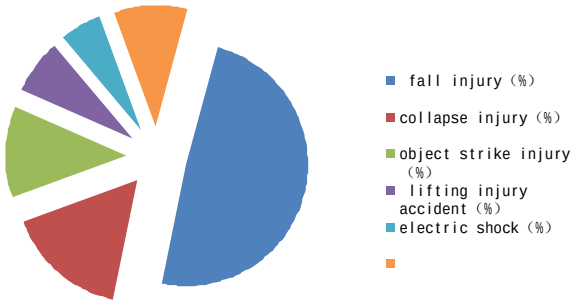

Fig.4.The distribution diagram of main accidents from 2004 to 2012

From table 1, the main accident types of construction accidents in China from 2004 to 2012 are falling injury, collapse injury, object strike injury, lifting injury and electric shock and so on.

From main accident accidents from 2004 to 2012 in the figure 4, 2004-2012 in China, falling injury was 49.17%, collapsed injury 16.09%, object strike injury 12.37%, lifting injury 7.20%, electric shock 5.31%. The above five accident types accounted for 90.14%. The other accident types accounted for 9.86%.

2.3 *The cause of the accident*

The accident data from 2004 to 2012 in construction industry were collected. By means of system engineering of logic thinking method, analyze these accidents. Summary up the main factors that lead to the occurrence of construction safety accidents, like human factor, material factor, environment factor and management factor[10]

(1) Human factor: The cause of human factor refers to the people's unsafe behavior in the process of production of all kinds of safety accidents. Unsafe behaviors are: operating errors, running operation, too fast feeding, talking and laughing in work, etc.

(2) Material factor: The reason of material factor refers to the content of the unsafe condition. The unsafe state refers to the lack of protection, insurance, signal device or defect and the disadvantages of equipment, facilities, tools, accessories and the defects of seat belts, safety helmet, safety shoes.

(3) Environment factor: Some accidents are due to people's unsafe behavior and unsafe state of the direct causes. Accidents caused by human negligence should also further research background conditions, namely the unsafe environment, such as too dark lighting, not clear operation field, narrow workplaces, etc.

(4) Management factor: People's unsafe behavior and unsafe state is the direct cause of the accident. And both have a direct relationship with the management. Therefore, mismanagement is the indirect cause of accidents.

CONSTRUCTION SAFETY ACCIDENT EARLY WARNING MODEL

Early warning index

Analyze and investigate the causes of ordinary construction accidents. Identify the following 48 causes that can result in construction safety accident, as shown in table 2.

Summary up the main factors that lead to the occurrence of construction safety accidents, like human factor, material factor, environment factor and management factor. And management factor is a reflection of people's subjective initiative. Management factors can be summarized to the human factor, as shown in table 3.

The construction safety evaluation system was shown in figure 5 of building based on figure 4.

Table 2 48 causes in construction safety accidents

1. Temporary buildings do not meet fire safety requirements.	17. Low price bidding	33. Dust, noise and light
2.Improper storage or use of hazardous chemicals	18.The disturbance of soil in the process of construction	34.Construction personnel is not healthy
3. The underground construction in quicksand and piping	19.Overload or extended operation of construction equipment	35. Rob time limit for a project
4.Substandard quality of construction equipment	20.Inadequate investment in safety management	36.Command against rules
5.Extreme climate and weather	21. The design change frequently	37.Safety inspection work is not in place
6.Mechanical, electrical equipment with "disease" operation	22.Construction personnel irregularities	38. The forecast is insufficient construction difficulty
7. The danger zone warning sign is unknown, is not complete	23. His hand mouth, unstable template support	39. The construction personnel fluidity is big
8.Alternating operation between man and lifting machinery	24. The construction of roads	40.Low technical level of construction personnel
9. Lifting crane and hoist structure instability	25.Inadequate lighting at night	41.Collapse of building structure
10.Improper use of electrical protection in wet conditions	26. The safety device failure	42. The underground gas overflow
11.Engineering components are lifted frequently.	27.Construction material quality is below standard	43. The blasting damage
12. The underground construction of the exhaust	28. Supporting system structure instability	44.Architectural design is not reasonable
13. Dietetic hygiene does not meet the standard, collective poisoning.	29.The engineering materials and components from falling	45. Backward construction technology
14. The foundation uneven subsidence, collapse.	30. The situation is unknown	46.Lack of safety awareness of construction personnel
15. Frequent lifting engineering components, materials	31. Professional and technical posts unlicensed mount guard	47. Temporary buildings to remove damage
16. The secondary construction destroy original building stability	32.Work in hazardous areas	48.Destruction of pipeline construction

Table 3 classification of construction safety accident cause

Classification of construction safety influencing factors	A collection of basic factors affecting security
Human factor	{ 8,11,13,16,17,20,21,22,31,34,35,36,37,38,39,40,44,45,46}
Material factor	{ 2,4,6,9,15 ,19,26,27,28,29,41,42,43,47,48 }
Environmental factor	{1,3,5,7,10,12,14,18,23,24,25,30,32,33}

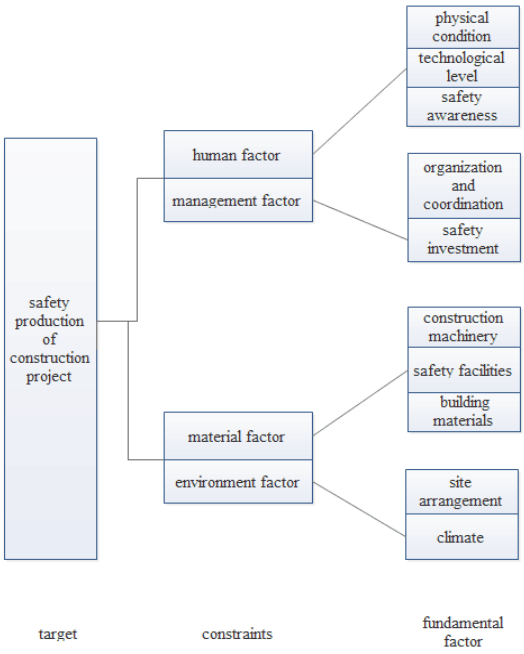

Figure 5 Construction safety evaluation system

Early warning model

Early warning model based on support vector classification in construction safety accident warning has the following advantages:(1) It can be directly over the probability density estimation and calculation according to the sample itself to solve the optimal decision function;(2) Solve the problem of over learning in a small sample. Early warning model in construction safety accident in fact is the process of classification and prediction. The merits of the early warning model depend on the decision function of classification and prediction.

The mathematical model of early warning method was set up for classification based support vector machine (SVM).

Alert degree is divided into two categories (with and without a warning), and the training sample is as:

$$(x_i, y_i), i = 1,...,l, y_i \in \{\pm 1\} \quad (1)$$

Among them, x_i shows l dimension warning signs index vector historical data; $y_i \in \{\pm 1\}$ shows warning degree classification, + 1 with warning, 1 without warning.

The goal of construction safety warning is to seeking the optimal classification function, as follows:

$$f(x) = \mathrm{sgn}[w \bullet f(x) + b], x \in R^n \quad (2)$$

Transform it into quadratic programming problems:

$$\max L(a) = \sum_{j=1}^{l} a_j - \frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l} y_i y_j a_i a_j K(x_i \bullet y_i) \quad (3)$$

Among them, $0 \le a_i \le C$, $\sum_{j=1}^{l} y_i a_i = 0, i = 1,...,l$, C with penalty factor.

The corresponding decision function is:

$$f(x) = \mathrm{sgn}[\sum_{sv} y_i a_i K(x_i \bullet y_i) + b] \qquad (4)$$

Among them, For the kernel function: $K(x_i \bullet y_i) = f(x_i) \bullet f(x_j)$.

Warning process

For safety accident warning work, firstly do feature selection. In order to reduce the extra workload and ensure the accuracy of the evaluation in the process, this paper chooses RS method to do feature selection. Table 4 can be gained after attribute reduction in table 3.

Table 4 feature selection after attribute reduction

1.Temporary buildings do not meet fire safety requirements	18.The disturbance of soil in the process of construction	34.Construction personnel is not healthy
2.Improper storage or use of hazardous chemicals	19.Overload or extended operation of construction equipment	36.Command against rules
4.Substandard quality of construction equipment	20.Inadequate investment in safety management	37.Safety inspection work is not in place
5.Extreme climate and weather	22.Construction personnel irregularities	40.Low technical level of construction personnel
6.Mechanical, electrical equipment with "disease" operation	25.Inadequate lighting at night	41.Collapse of building structure
8.Alternating operation between man and lifting machinery	27.Construction material quality is below standard	44.Architectural design is not reasonable
10.Improper use of electrical protection in wet conditions	29.The engineering materials and components from falling	46.Lack of safety awareness of construction personnel
11.Engineering components are lifted frequently.	32.Work in hazardous areas	48.Destruction of pipeline construction

The second step of warning is to realize the training set. The second step took the rest of the 24 as a training set based on feature selection. The training data is a 24 d vector, as $\{x_1, x_2, \ldots, x_{23}, x_{24}\}$.Use training sample model of *x* city nearly 16 years, and take the first 11 years of data as the training sample, the recent 5 years of data as test data. Each data is represented as 24 indicators. Each evaluation index x_i uses 0 and 1, 0 indicating without warning, 1 indicating with warning.

The third step is for knowledge acquisition of SVC. This paper describes the classification of SVC for training to get the decision function.

$$f(x) = \mathrm{sgn}[w \bullet f(x) + b] = \mathrm{sgn}[\sum_{i}^{24} y_i a_i (x_i, x) + b] \qquad (5)$$

Kernel function is adopted:

$$K(x, x_i) = \exp(-\frac{\|x - x_i\|^2}{2s^2}) \qquad (6)$$

To realize the training and prediction process in Matlab and obtain the most accurate prediction results. The predicted result was shown in table 5 when $g = 0.01, s^2 = 0.05$.

Table 5 Warning results compared with the actual result

annual	The data before the reduction	After the reduction of data	The truth
2009	warning	warning	warning
2010	warning	warning	warning
2011	No warning	warning	warning
2012	No warning	No warning	No warning
2013	warning	warning	warning
accuracy	80%	100%	

After comparison, it can be seen that the RS theory is helpful to improve the prediction accuracy of SVC after using to reduce the sample data. Calculation process will be more quickly due to the shrinking of sample data.

CONCLUSION

Summary up the main factors that lead to the occurrence of construction safety accidents, like human factor, material factor, environment factor and management factor. Construction safety accident early warning model had been established based on support vector machine. Then analyze the practical feasibility of early warning model. It not only provides a new method for the accurate early warning of safety accidents, but also provides a theoretical support for the prevention of safety accidents. It can be seen that the RS theory is helpful to improve the prediction accuracy of SVC after using to reduce the sample data.

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