Causes of Work Safety Accidents in Railway Construction Engineering

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Abstract. Work safety accidents that occurred in railway construction engineering could cause casualties and economic losses. Analyzing the trends and causes of accidents is helpful to reduce the occurrence of an accident. In this paper, the 108 work safety accident cases from 2005 to 2020 are collected and analyzed by statistical method. The complex network theory is used to construct causation model in collapse accident. The analysis results show that from 2015 to 2020 the largest number of accidents that occurred during railway construction are in lines, followed by tunnels and bridges-culverts. The occurrence frequency of work safety accidents from May to July is significantly higher than other months. The results also show that the nodes (construction personnel operate in violation of rules and regulations and inadequate management in construction site) are of high value.

1. Introduction

Railways are a means of transportation that helps people get around quickly. However, during construction of railway, work safety accident happened occasionally, resulting in casualties and economic losses. For example, on November 20, 2007, 35 people died in a severe collapse in Enshi city, Hubei province. On October 29, 2011, a vehicle transporting construction workers overturned in Manwa township tunnel on the line of Lan-Yu Railway, resulting in 24 deaths and four serious injuries.[1]

To effectively prevent work safety accidents in railway construction projects and strengthen risk control, it is imperative to explore cause factors of accidents.

Scholars at home and abroad used different methods to analyze the causes of accidents. Zhang Wei et al. built a network model of tower crane safety accidents and analyzed the critical causes of tower crane safety accidents.[2]Xu Wei et al. used the Apriori algorithm to mine the association rules of railway accident causation and build the network of railway accident causation.[3]Chen Wenying et al. used complex network theory to make a network model of work safety accidents in an urban area of Beijing. They studied the distribution characteristics of nodes by calculating degree and other statistical indicators.[4]

However, few people have carried out network about the cause factors of work safety accidents in railway projects. Because the work safety accident of railway project is different from the railway traffic accident and all kinds of work safety accidents, the analysis of this kind of accident is of great significance to ensure the safety of personnel during railway construction.

Based on the existing research, this paper collects the data of work safety accidents during construction of railway, and uses the complex network theory to construct cause factor network of work safety accidents. By analyzing the characteristics of factors network, we can efficiently deal with
the complicated data of railway accidents, excavate the accident mechanism and assist the decision-making of safety supervision during railway construction.

2. Statistic analysis of work safety accidents in railway construction engineering

2.1. Data source
The data that this paper used are collected from CNKI, National Railway Administration, related book[5], and Safety Management Network. There are 108 cases of work safety accidents that occurred during railway construction from 2005 to 2020.

2.2. Time series analysis
The number and death toll of work safety accidents in railway construction projects from 2005 to 2020 are shown in the figure. As can be seen from Figure 1, in the past 15 years, the railway construction project with the largest number of accidents is line engineering, followed by tunnel engineering, bridge and culvert engineering. Large and above work safety accidents mainly occur in tunnel engineering, line engineering, and bridge-culvert engineering, among which tunnel engineering work safety accidents cause the largest number of deaths.

![Figure 1: Statistics of the major work safety accidents in different professional engineering from 2005 to 2020](image-url)

As can be seen from Figure 1, in the past 15 years, the largest number of accidents about the railway construction project is line engineering, followed by tunnel engineering, bridge and culvert engineering.

In tunnel, line, bridge and culvert engineering, large and above work safety accidents happen frequently. Although the occurrence of large and above work safety accidents in tunnel engineering is not frequent, the death toll is the largest.
It can also be seen from Figure 2 that there are specific gaps in the number of work safety accidents during railway construction in the months. The occurrence frequency of work safety accidents from May to July is significantly higher than other months. The occurrence frequency of work safety accidents in December is higher. The seasonal change of the number of large and above work safety accidents is not apparent.

2.3. Spatial analysis

As shown in Figure 3, there are gaps in the region frequency of work safety accidents as well. The number of work safety accidents in Hubei province, Shandong province, Hebei province, Shanxi province and Gansu province is more than that in other regions.
From 2007 to 2020, there are ten work safety accidents during railway construction in Hubei Province, ranking first in the country, accounting for 9.17%, of which six work safety accidents occurred in 2019.

The existing regional differences are related to the unbalanced area scale, the geological terrain conditions and natural climate (complex terrain, temperature and rain, construction period length, etc.). In addition, the supervision of railway construction is also closely related.

3. Causation Model of work Safety Accident in Railway Construction Engineering Based on Complex Network

3.1 Complex Network theory

The complex network is established on the graph theory and statistical physics, which is widely used in various disciplines and is a powerful tool to expound system complexity.

The work safety accident of railway that construction studied in this paper is a complex, including unsafe behavior of people and machine, weather and so on. The accident type and accident causative factors are taken as nodes, and the logical connection between nodes is taken as edges to form a complex network with a topological structure. The node degree of the network is calculated to analyze.

Node degree is defined as the number of edges directly connected to node I. In a directed network graph, the total degree of a node is composed of the outgoing degree and the incoming degree, i.e

$$K_I = K_{I}^{\text{out}} + K_{I}^{\text{in}}$$

where $K_I$ is the total degree of nodes; $K_{I}^{\text{out}}$ is the output degree of node; $K_{I}^{\text{in}}$ is the entry degree of the node.

3.2 Accident node

Analyzed relevant literature and regulations on work safety, we sorted out the causative factors of accidents from the database, and obtained the classification of accident nodes, as shown in Table 1.

| Accident type node | Accident cause factor node |
|--------------------|---------------------------|
| 1. Collapse; 2. Mechanical damage; 3. Falling from high places; 4. Object strike; 5. Lifting injury; 6. Get an electric shock; 7. Explosion; 8. Fire accident; 9. The permeable; 10. Vehicle injuries; 11. Other |
| Person |
| 1. Construction personnel operate in violation of rules and regulations; 2. Weak safety awareness among construction workers; 3. Poor construction quality; 4. Improper design by designers; 5. Misoperation of construction personnel; 6. Alter the design and construction without authorization; |
| Machine |
| 7. Poor quality of equipment and materials; 8. Mechanical equipment failure; 9. Improper mechanical design |
| Environment |
| 10. Geological; 11. The precipitation; 12. Other |
| Management |
| 13. Insufficient safety supervision; 14. Insufficient qualification of construction personnel/enterprise; 15. Offending command at the construction site; 16. Illegal contracting/bidding; 17. Inadequate construction site management; 18. Unreasonable safety training of construction personnel |

The occurrence of all kinds of accidents involves the complex cause system formed by the four main factors of person, machine, environment, and management. For the occurrence process of each accident, the accident causative chain can be extracted: initial event node 1- factor node 2-⋯- factor
node n- accident consequence node. The work safety accident network of this kind of event is formed by analyzing all accident cases.

3.3 Collapse accident
This paper takes collapse accident as an example to build a cause factors network model. We sort out the cause factors from collapse accident cases, and finish the accident chain. Pajek software is used to construct the collapse network.

![collapse_network.png](attachment:image)

The degree value of node 1 (construction personnel operate in violation of rules and regulations) and node 17 (inadequate construction site management) is apparently higher. It can be seen that people's unsafe behavior and the lack of management are the main reasons leading to railway safety work accidents.

![degree_value.png](attachment:image)

4. Conclusion
Based on the results and discussions presented above, the conclusions are obtained as below:
(1) It is shown that from 2015 to 2020, the largest number of accidents that occurred during railway construction were in lines, followed by tunnels and bridges-culverts.

(2) The occurrence frequency of work safety accidents from May to July is significantly higher than other months.

(3) The results also show that the nodes (construction personnel operate in violation of rules and regulations and inadequate management in construction site) are of high value.

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