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An Analysis of Construction Accident Factors Based on Bayesian Network

[1]Yunsheng Zhao and [1, 2]Jinyong Pei
[1]College of Engineering, China University of Geosciences, Wuhan 430074, China
[2]China Three Gorges Project Corporation, Beijing 100038, China

Abstract: In this study, we have an analysis of construction accident factors based on bayesian network. Firstly, accidents cases are analyzed to build Fault Tree method, which is available to find all the factors causing the accidents, then qualitatively and quantitatively analyzes the factors with Bayesian network method, finally determines the safety management program to guide the safety operations. The results of this study show that bad condition of geological environment has the largest posterior probability; therefore, it is the sensitive factor that might cause the objects striking accidents, so we should pay more attention to the geological environment when preventing accidents.

Keywords: Bayesian networks, construction accident factors, posterior probability, prior probability

INTRODUCTION

Nowadays, the control of the project construction accidents has become more stringent and how to reduce the project construction accident has become more and more urgent, so we need a viable solution for a detailed analysis of the failures to develop appropriate measures to reduce the occurrence of similar accidents. Xie *et al*. (2004) study the Bayesian networks to improve the fault tree method. Liu and Qin (2004) analyze the network safety assessment based on Bayesian networks. Zhang *et al*. (2005) have a research of the quantitative analysis of fault tree based on bayesian network. Li (2006) study the quantitative risk assessment of long-distance pipeline based on fault tree analysis. Lou (2004) has a research of the Bayesian network in mechanical fault diagnosis. Liu and Zeng (2007) study the applications of Bayesian networks in coal mine production safety evaluation system. Zhou (2006) study the probabilistic safety assessment and application based on bayesian networks.

This study focuses on statistical analysis of the accident and the development of safety management solutions. Use Bayesian network to do the statistical analysis of the occurred objects striking accidents in Xiluodu project from 2004 to 2006.

ANALYSIS OF THE FACTORS CAUSING ACCIDENTS

From 2004 to 2006 there had been 50 cases of construction accidents in Xiluodu project, in which included 22 death cases causing 27 deaths and 20 serious injury cases causing 29 seriously injured persons. In this 50 cases of accidents, the objects striking accidents accounted for 17 cases, in which there are 13 cases of serious injury and 4 cases of death. It can be seen the objects striking accidents is a major part of the accidents in Xiluodu project. Due to limited space, I only analyzed the objects striking accidents in this study.

According to the analysis of the cause of the objects striking accidents carefully, we can know all of the reasons can be divided into two cases: direct causes and indirect causes.

Direct causes:

- **Unsafe (mechanical, physical or environmental factors):** The poor geological structure leads to mountain rock-fall. Safe distance is not enough; the construction environment is poor, noise, inadequate lighting, etc
- **Unsafe acts (human factors):** Safety education and training is not enough; the safety knowledge and awareness of the operating personnel are weak and lack of self-awareness of security, operation team do not set picket. High operating is illegal, without proper use of the individual labor protection products (such as seat belts) and lack of the necessary safety knowledge, the management of safety guard officers is poor, Inadequate pre-construction inspection, etc

Indirect causes: The organization of the construction unit is unreasonable; the operating process is without warning; No specific pre-construction safety disclosure; the safety awareness of workers is weak, etc. The above causes can be summarized as shown in Table 1.

Corresponding Author: Yunsheng Zhao, College of Engineering, China University of Geosciences, Wuhan 430074, China

Table 1: List of the causes of object against accidents

Code	The causes of objects striking accidents	Description
X_1	Lack of self-protection	Construction workers lack Self-protection
X_2	Operation in hazardous locations	Construction workers work in unsafe places
X_3	Poor geological environment	Geological structure of the mountain is loose, and prone to natural geological disasters
X_4	Poor workplace environment	Including the climate and environment, and the light , the noise etc
X_5	Improper location of construction facilities	Improper location of construction facilities lead to accidents
X_6	Alert work do not well	Including failure to set alert identification, barrier protection and other related measures and no risk warning to construction workers
X_7	Safety equipments are not in place	When necessary, do not use safety equipments, such as seat belts,
X_8	Safe distance is not enough	The distance from the hazard is not enough
X_9	Safety education is not enough	Including the education of employee safety awareness and safety skills training
X_{10}	No safetytests	The person in charge of the construction project do not conduct safety tests
X_{11}	Safety checks are not in place before construction	Before construction did not conduct a comprehensive inspection of the factors that may cause the accident
X_{12}	Illegal operations	The lack of safety awareness training lead to Illegal operations

Table 2: List of Xiluodu project safety events

Code	Event	Description
A	In hazardous areas	Including the hidden dangers in the workplace or the safety distance is not enough
B	Lack of safety awareness	Staffs' awareness of risk is weak
C	Safety mismanagement	Including safety equipment is not in place, alert work is not in place, safety training is not in place, etc
D	Inadequate preparation	Including pre-construction inspection is not in place, not for safety tests, etc.
E	Management and organizational issues	Including safety management and preparations is not in place, etc.
F	Environmental issues	Including the geological environment and climate surrounding, etc
G	Objects striking accidents	Accidents caused by the object against

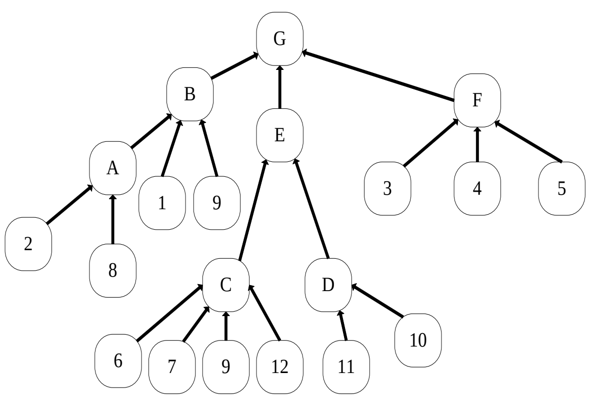

Fig. 1 The Bayesian network of objects striking accidents

BAYESIAN NETWORK ANALYSIS

Bayesian network, also known as Bayesian reliability networks, which is combination of graph theory and probability theory (Liu and Qin, 2004). It can be intuitively expressed as an assignment causal relationship graph and can get joint probability distribution which contains all nodes according to the prior probability distribution of the root node and the conditional probability distribution of the non-root nodes (Zhou, 2006). Exactly this study did qualitative and quantitative research on the factors in the accidents by this method.

In order to build a Bayesian network of the objects striking accidents in Xiluodu project, we set the safety events in Table 2 according to Table 1 (Liu and Zeng 2007).

According to the relevant principles of Bayesian networks and Table 2 and 1, we can get the Bayesian networks of the objects striking accidents shown in Fig. 1 (Xie *et al.*, 2004).

Counting all of the objects striking accidents in Xiluodu project, we can get Table 3 and Table 4, in which the table column refers to the every objects striking accident, two types of importance, 1 and 0.8, which is used to distinguish between fatalities and serious injury accidents, 1 is expressed as deaths and 0.8 is for the serious injuries, to emphasize the seriousness of the accidents. The probability of each basic cause represents its contribution to the objects striking accidents on the basis of that the objects striking accident has happened, For example, in the 1.05 accident, The probability of X3 is relatively large, indicating X3 plays a leading role in the occurrence of the accident, at the same time we also consider that an accident cause serious injury or death, accumulating the degree of these impacts we can get a Initial priori probability of each basic cause.

In the Fig. 1, I represent Xi (i = 1, …, 12). In the Table 4, the value of the total column is added up by the weight, such as the total value of X1 is:

$$(0.1+0.2+0.15+0.15+0.1+0.2+0.1+0.1)*0.8+(0.1+0.1)*1 = 1.3$$

Table 3: The statistical probability of objects striking accidents' basic causes

Accident date	Importance coefficient	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
1.05	0.8	0.1	0.1	0.5			0.15	0.15					
4.11	0.8				0.1	0.1		0.6		0.2			
6.14	0.8	0.2	0.2				0.3		0.1	0.2			
10.06	0.8	0.15	0.15	0.6							0.1		
12.28	0.8	0.15	0.15			0.5				0.2			
8.09	1	0.1		0.6								0.3	
1.29	0.8	0.1		0.5			0.2				0.1	0.1	
2.03	0.8	0.1		0.6							0.1	0.2	
2.25	0.8	0.15	0.15			0.5				0.1			0.1
2.28	0.8	0.1	0.1	0.5			0.2					0.1	
3.19	0.8			0.8								0.2	
5.11	0.8	0.1					0.4				0.2	0.3	
6.11	0.8	0.2	0.1		0.5					0.2			
4.4	1			0.8								0.2	
7.28	1	0.1	0.1	0.6						0.2			
9.5	1			0.6				0.2		0.1	0.1		
1.12	0.8	0.1	0.2		0.3					0.2	0.1	0.1	
Total		1.36	1.02	5.4	0.72	0.88	0.88	0.68	0.08	1.18	0.58	1.3	0.08
Probability		0.096	0.072	0.381	0.051	0.062	0.062	0.048	0.0056	0.083	0.041	0.092	0.0056

Table 4: The probability of objects striking accidents' basic causes

Basic cause code	Probability	Basic cause code	Probability
X_1	0.096	X_7	0.048
X_2	0.072	X_8	0.0056
X_3	0.381	X_9	0.083
X_4	0.051	X_{10}	0.041
X_5	0.062	X_{11}	0.092
X_6	0.062	X_{12}	0.0056

Table 5: The basic cause probability when objects striking accidents do not occur

Basic cause code	Probability	Basic cause code	Probability
X_1	0.03	X_7	0.03
X_2	0.04	X_8	0.005
X_3	0.005	X_9	0.03
X_4	0.03	X_{10}	0.03
X_5	0.02	X_{11}	0.02
X_6	0.02	X_{12}	0.01

Table 6: The prior probability and posterior probability of basic cause

Code	Factor	Prior probability	Posterior probability
X_1	lack of self-protection	0.096	0.0000656
X_2	Operation in hazardous locations	0.072	0.0000369
X_3	Poor geological environment	0.381	0.0000156
X_4	Poor workplace environment	0.051	0.0000348
X_5	Improper location of construction facilities	0.062	0.0000635
X_6	Alert work do not well	0.062	0.0000635
X_7	Safety equipment is not in place	0.048	0.0000327
X_8	Safe distance is not enough	0.0056	0.0000229
X_9	Safety education is not enough	0.083	0.0000567
X_{10}	No safety tests	0.041	0.0000028
X_{11}	Safety checks not in place before construction	0.092	0.0000943
X_{12}	Illegal operations	0.0056	0.0000114

The probability of basic cause:

P(X1/T) = 1.3/(13+1.0+5.4+0.7+0.8+0.8+0.68+0.08+1.18+ 0.58+1.3+0.08) = 0.096

According to Table 3 and 4, set the prior probability of the X1-X12 shown in Table 5; in order to facilitate the analysis, empirically set the probability of each basic cause when the accident does not occur shown in Table 6 (Zhang *et al*., 2005).

Using fault tree analysis (Li, 2006), we can get:

P(T) = [(0.072+0.0056)*0.096*0.083](0.062+0.048+0.083 +0.041+0.092+0.0056) *(0.381+0.051+0.062) = 0.0000205

According to formula 1 (Lou, 2004):

$$P\ (T|\ (Xi) = (P(Xi|T)*P(T))/P(Xi) \qquad (1)$$

We can obtain posterior probability of each basic cause, as shown in Table 6.

As we know, posterior probability can reflect the basic cause influence on the top event, As it can be seen from Table 6 , the Posterior probability of basic cause X3 is 0.00156, which is the largest of all the posterior probability of basic causes, Therefore, X3 is the most sensitive factor in the objects striking accidents, so we can analyze the possible factors of un-safety according to prospecting the geological details of construction sites and then develop appropriate programs and operating procedures of construction, so that we can reduce the probability of occurrence of X3 and then reduce the probability of the objects striking accidents.

CONCLUSION

For the Bayesian networks, the current use of accident analysis is a static Bayesian networks, can not be reasoning over time. With the development of Dynamic Bayesian Network, the dynamic Bayesian model and its prediction algorithm has more advantages when it is used to analyze the unexpected incidents and predict consequences. At the same time, considering adding information based on expert experience and the state transfer function of subjective judgments to calculate the probability distribution of each variable of the next time slice will be focus in future research.

This analysis method was validated reasonable through a variety of examples. However, in practical engineering applications, there may be a lot of problems, so must be handled accordingly with the actual situation. Since there may be a deviation between Bayesian network model built and the actual system, therefore need to do some necessary improvements to the model to ensure the consistency of models and systems. The structure and parameter learning function of Bayesian network just provides a good idea for this problem, there are many problems to be solved in this direction. Apply the model to test its feasibility in practical engineering and then revise, develop and perfect constantly. Use the Probabilistic Safety Assessment based on Bayesian network to guide safe design, safe growth, safe diagnosis and other engineering work. At present, China has not yet matured software for building the Bayesian Network Model, In addition existing tools can not be extended to develop graphical modeling software of Bayesian network analysis.

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