

doi:10.21311/002.31.3.13

A Study on the Management Factors of Transportation Accidents of Dangerous Chemicals: from the Perspective of Bayesian Network

Yajing He¹, Xiaheng Zhang², Tianshan Ma¹

¹School of Economics and Management, Chang'an University, Middle section of the South Second Ring Road, 710064, Xi'an, China

²Business School, Northwest University of Political Science and Law, No.558 West Chang'an Avenue, 710122, Xi'an, China

Abstract

Management directly impacts the occurrence of the direct factors of the accidents. Unfulfilled management is the incentive of transportation accidents of dangerous chemicals. In order to investigate the influence path and the degree of the management factors in the accident cause system, with the help of the structural equation model, a hypothesis relationship between the management factors and the influence of direct accident factors is constructed, analyzed and verified. Furthermore, via the Bayesian network model, the cause system is intuitively described, the posterior probability of each management factor under each state of the accidents is calculated, and suggestions are provided to reduce the accident rates and to strengthen the safety production management.

Keywords: transportation management of dangerous chemicals; transportation accidents; structural equation model; Bayesian network

1. INTRODUCTION

Dangerous chemicals are highly toxic chemicals and other chemicals that harm human body, the facilities and the environment, with features of poison, corrosion, explosion, combustion, combustion-supporting, etc. In the event of transportation accidents of dangerous chemicals, tremendous financial loss and social influence are caused. According to relevant statistics, more than nearly 40% of road accidents involving explosion, leakage and other accidents of hazardous chemicals occur during transportation. As a major mode of transporting dangerous chemicals, road transport is of strong expertise, high risk factor, and relatively high management difficulty. Most of the risk sources are the controllable factors that fall into the scope of management. In other words, they are controlled and prevented through the effective safety management measures. The improvement of the security awareness and the quality level of the practitioners reduces the human factor risk. The enhancement of maintenance and the hidden danger identification of the vehicle equipment reduces the cargo factor risk. The updates of emergency self-rescue protective equipment reduce the risk of the environment. If the management is vulnerable, latent

danger of the accidents would spread without any defense, which is called the management risk factors. Specifically, it refers to the safety negligent acts of the enterprises and the supervision loopholes of the administrative department. Therefore, humans, vehicles and the environmental factors are the direct causes of the accidents, and the management factors are the root causes and the basic motivation of the generation of these three factors.

One aspect of the study on defending the transportation accidents of dangerous chemicals is how to understand the relationship between the direct causes and the management factors, as well as the importance degree of the management factors. Thus, the accident causes under the current regulatory system of dangerous chemicals transportation are summarized. The impacts of humans, objects and the environmental factors on the security system construction of dangerous chemicals transportation are combed. Also, the management causes behind the occurrence of each element are explored. All of them give reference to the further study on accident prevention and ensure safe and smooth transportation of dangerous chemicals.

2. LITERATURE REVIEW

In the aspect of the analytical method of accident cause, Bu and other researchers have applied the fault tree analysis method to identify the risk sources (Bu et al., 2014); Bagheria has proposed the risk source identification model based on the consequences of transportation accident (Bagheria et al., 2012); Zhang has applied the method of analytic hierarchy process to establish the safety management evaluation model (Zhang et al., 2009); Krejci assesses the risks through analyzing the load distribution of the risk levels (Krejci and Bambusek, 2012); Qiu has proposed the quantitative analysis method for transportation accidents of dangerous chemicals based on VBSS and the belief function theory (Qiu et al., 2015); Hu has analyzed the cause of transportation accidents of dangerous chemicals by means of the accident probability method (Hu and Cao 2015; Bonvicini and Spadoni, 2005).

From the aspect of the risk factors during transportation, Thierheimer and other researchers have evaluated the risks during the whole transportation process, including human factors, vehicle factors and environmental factors (Liu et al., 2012; Thierheimer et al., 2010); Kirytopoulos has studied the organizational factors and the human factors of the risks (Kirytopoulos et al., 2014); Mou has proposed the assessment model and the procedures concerning the environmental risk factors (Mou, 2010).

In terms of the relationship between indicator identification and management factors, Liu has proposed the significance of policy management for the transporters to comply with the law and protect the environment (Liu et al., 2011); Dong has presented the factor structure that affects production safety and the importance of safety management (Dong et al., 2013).

From the perspective of the occurrence probability of the causes of dangerous transportation accidents, Kazantzi has clarified the impact of the occurrence probability of

different risk events made on the transport cost(Kazantzi et al., 2011); Bayesian et al. have applied the Bayesian method to analyze the occurrence probability of the accidents (Schubert et al., 2012; Yang et al., 2015; Adedigba et al., 2016; Shishkina, 2015; Qaziet al., 2015); Baksh has employed the Bayesian method to calculate the posterior probability of the occurrence of adverse events(Baksh et al., 2015); Khakzad has used approximate reasoning of the major accidents as precursor data to predict the occurrence probability of the major accidents (Khakzad et al., 2015).

Through literature review, it is found that existing research mainly lays emphasis on the safety management evaluation for the enterprises, and the pros and cons of the entire management system, including the functional government departments, are less mentioned. Also, particular stress is put on the study on the independent action of direct factors like humans, objects and environment, as well as the importance of management. There has been no analysis of the important causal relationship, namely, the management factors are the potential incentives of the above-mentioned three factors. The isolation of the causal chain would lead to the uncomprehensive exploration of the accident causes. This paper analyzes the direct cause and the management of indirect reasons of the accidents, uses the SEM Model to construct the influence path of internal elements of transportation management of dangerous chemicals, and analyzes and verifies the hierarchical relationship between humans, objects, environment and the management factors. The Bayesian network method is used to build up a network topology map of the accident causes, and to explore the conditional probability distribution and the changes of the direct accident causes and indirect management incentives.

3. THE CAUSAL RELATIONSHIP BETWEEN THE DIRECT CAUSES AND THE MANAGEMENT FACTORS OF TRANSPORTATION ACCIDENTS OF DANGEROUS CHEMICALS

3.1 Occurrence Mechanism of the Accidents

The main causes of transportation accidents of dangerous chemicals include traffic accidents caused by rear-end collisions, crash and overloading which result in tank damage, the aging transport vehicles and equipment that lead to the leakage of dangerous chemicals, the improper handling of toxic substances that infect humans and animals and pollute the environment, as well as the ignition and the explosion of combustible materials in case of chemical reaction. Behind these incidents are the reflection of negligent management loopholes. Overloading and collision are taken as the examples to analyze the internal relationship between the management factors and the occurrence of accidents, as shown in Figure 1.

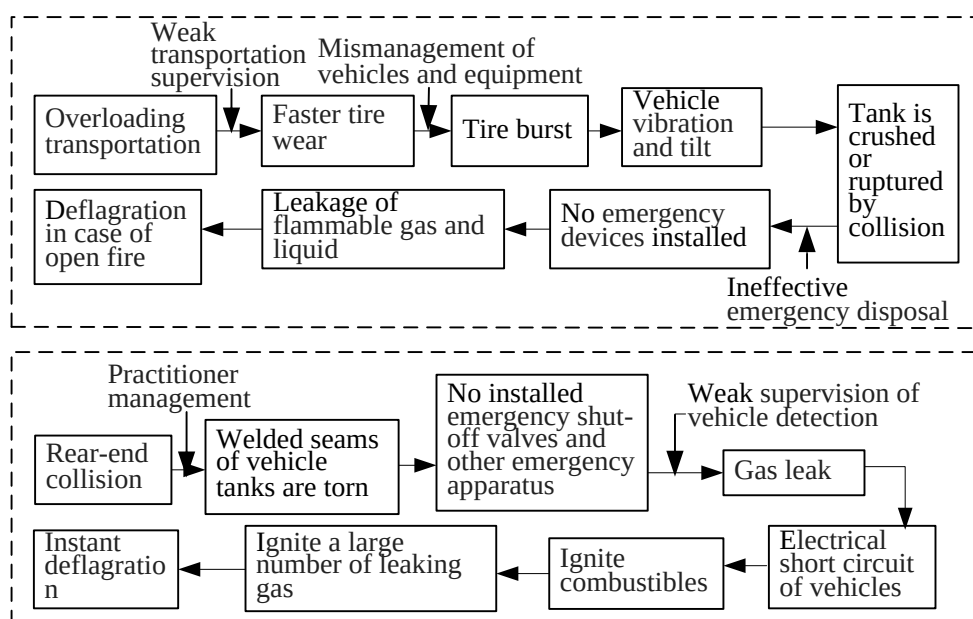


Figure 1. The mechanism analysis of transportation accidents of dangerous chemicals.

Vehicles and equipment management, practitioner management, emergency management, transportation market management, etc., run throughout the whole process of dangerous chemicals transportation and influence transport safety. In addition, the transport security is also affected by transportation planning approval route management, transportation process management, transportation enterprise assessment management and other main factors. The direct causes of the accidents include vehicle collision, overloading, over-limit, driving error, and aging equipment. Negligent management loopholes are the indirect accident causes. Thus, management improvement is able to largely avoid the occurrence of the direct causes and to reduce the accident probability. To study the relationship between the direct causes and the management of indirect causes, this paper uses the structural equation model and conducts hypothesis testing on the influence path, as shown in Figure 2.

3.2 Theoretical Assumptions

Transportation enterprises are the main entity responsible for the transportation safety production of dangerous chemicals. The practitioner management of the enterprises is mainly reflected in staff recruitment and training. The management of vehicles and equipment is embodied in its operation and maintenance. Emergency rescue management refers to the self-rescue facilities of the enterprises and the construction of the emergency system. Transportation management is the supervision of the implementation of the basic practices.

H1a: the internal safety management of dangerous chemicals transportation enterprises has a path impact on the practitioner management;

H1b: the internal safety management of dangerous chemicals transportation enterprises has a path impact on the equipment of vehicles and facilities;

H1c: the internal safety management of dangerous chemicals transportation enterprises has a path impact on the emergency rescue management;

Competent communication and transportation departments at all levels and their affiliated transport regulatory agencies assign their responsibilities for dangerous chemicals transportation in the principle of "one level of approval and four levels of supervision". Also, they assume the duties of prior approval, process supervision and after management in the aspects of vehicles, container equipment, personnel qualification, enterprise safety management systems and emergency rescue system of the transportation enterprises.

H2a: the industry management of dangerous chemicals transportation of the transportation sector has a path impact on the practitioner management;

H2b: the industry management of dangerous chemicals transportation of the transportation sector has a path impact on the equipment of vehicles and facilities;

H2c: the industry management of dangerous chemicals transportation of the transportation sector has a path impact on the emergency rescue management;

Other departments, such as public security, quality inspection, environmental protection, health, industry and commerce and taxation and customs, formulate the related laws, regulations and industry standards for the industry management of dangerous chemicals transportation, standardize the operating procedures during transport, and play the role of guidance, supervision and management in the whole process of transportation.

H3a: the transportation management of dangerous chemicals of other departments has a path impact on the practitioner management;

H3b: the transportation management of dangerous chemicals of other departments has a path impact on the equipment of vehicles and facilities;

H3c: the transportation management of dangerous chemicals of other departments has a path impact on the emergency rescue management;

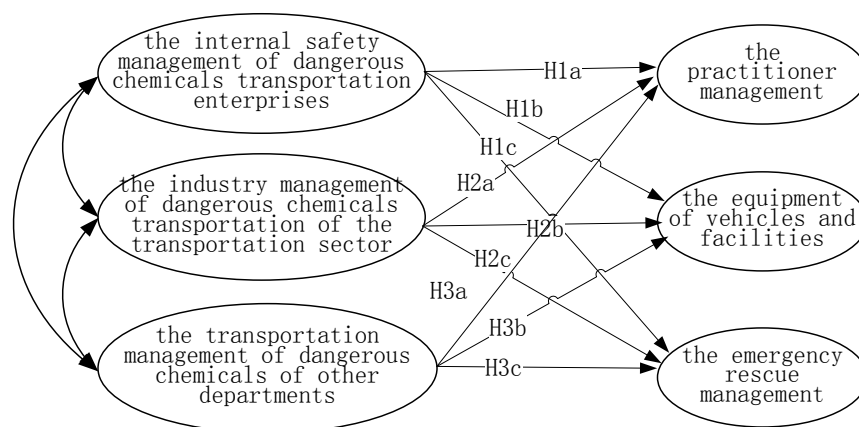


Figure 2. Hypothetical relationship path of the theoretical model.

Tabla 1 Influencing mechanism hypothesis of exogenous latent variable on endogenous latent variables

Variables	Measurement indicator design The core content	Direct causes of the accidents
The internal safety management of dangerous chemicals transportation enterprises	Normative employment system	Mismanagement of practitioners Mismanagement of vehicles and equipment Mismanagement of transportation process
	Daily education management and regular training of the personnel	
	Vehicle loading specifications	
	Regular comprehensive inspection and maintenance of the vehicle equipment	
	Emergency response system and measures and emergency drills	
	Security inspection before the vehicles set out	
	Road checks and hidden dangers identification	
The industry management of dangerous chemicals transportation of the transportation sector	Supervise the road transport permits for the vehicles and transport permits for dangerous chemicals	Mismanagement of transportation process
	Supervise practitioners' legitimate use of the road transport permits	
	Supervise whether the transport enterprises operation projects are adjusted or not	
	Evaluate safety production management system and procedures	

The transportation management of dangerous chemicals of other departments	Supervise legitimate cargo transport	
	Supervise standard vehicles and equipment	
	Supervise random parking	
	Supervise overspeeding and overloading	
	Illegal driving, etc.	
Practitioner management	Complete personnel allocation	Negligence and operation violation No identification of the hidden dangers Fatigue driving and operation in spite of illness Substandard driving Lack of emergency self-rescue
	Overall quality level of the personnel	
	Security awareness training efforts of the personnel	
	Security assurance of the personnel	
Management of vehicles and equipment	The legality of vehicle operation	Substandard and disqualified vehicles and equipment Illegal modification of trucks Out-of-scope transportation Aging vehicle and equipment and operation in spite of illness
	Technical condition of vehicles	
	Vehicle inspection and maintenance	
	Vehicle installment information system	
	Safety routine inspection and hidden danger identification of the equipment	
	Suspension of vehicle identification plate	
Management of transportation process	Timely emergency self-rescue and departmental rescue	No emergency shut-off valve and other emergency equipment No emergency rescue preparation Leakage during loading and unloading
	The legality and compliance of packaging and handling	

3.3 Data and Hypothesis Test

Design the source of scale and data: questions in the questionnaire are set on the main basis of the assumed content in Table 1. The Likert five-scale sheet is adopted. Data is filled in by the professionals, including practitioners, experts, industry executives and other objects. 203 effective questionnaires are collected by means of online questionnaires, field questionnaires, etc, to meet the demands for sample analysis of the structural equation model.

Hypothesis fitting test: Spss 21.0 and AMOS 21.0 are used to test whether the hypothesis of the structural equation model is valid. The value of coefficient α in the scale is 0.841, indicating that this scale has a favorable reliability. In the KMO test and the Bartlett

sphericity test, the overall KMO value of the scale and the KMO values of various measurement indicators are greater than 0.700. The Sig value of statistic magnitude in the sphericity test is less than 0.01, which indicates that there exists a correlation between these variables. The loadings of the measurement indicators on their attributive factors are greater than 0.500, indicating that the scale has favorable discriminant validity. The value of significance probability > 0.05 . The values of other fit measures, such as RMR value and the ratio of chi-square degree of freedom, all reach an acceptable standard of the hypothesis model.

According to Table 2, by testing the research hypothesis, the results indicate that the assumptions of H1c, H2a, H2b, H2c are refused, and the assumptions of H1a, H1b, H1d, H2d, H3a are accepted.

Tabla 2 Result of Hypothesis Test

Research hypothesis	Estimate	S.E.	C.R.	P	Results
H1a	2.247	1.896	2.185	0.002	Accept
H1b	0.261	0.307	2.849	***	Accept
H1c	0.068	0.123	2.554	***	Refuse
H1d	0.249	0.187	2.333	0.006	Accept
H2a	-0.101	0.265	-2.383	0.702	Refuse
H2b	-0.720	0.827	-2.870	***	Refuse
H2c	-0.183	0.145	-2.261	0.002	Refuse
H2d	0.624	0.373	2.673	***	Accept
H3a	0.324	0.307	2.057	***	Accept

NOTE: If $p < 0.001$, the symbol "***" will be displayed.

4. ANALYSIS ON MANAGEMENT FACTORS OF TRANSPORTATION ACCIDENTS OF DANGEROUS CHEMICALS BASED ON THE BAYESIAN NETWORK

4.1 The Establishment of the Bayesian Network Structure

The structural equation model determines the relationship between the direct and indirect causes, thereby establishing a causal model diagram. If the model diagram is transformed as the Bayesian network, the proportion changes of each management factor when transportation accidents of dangerous chemicals happen are able to be inferred. The Bayesian network exerts prominent effects when dealing with the problem of probability at uncertain conditions. This paper uses the Bayesian network to analyze the cause system of the transportation accidents of dangerous chemicals, with an aim to identify the relationship between state variables that influence the accidents and their probabilities.

The set of defined variables $V=\{X_i\}, i=1, \dots, n$. Each variable corresponds to a node, and the directed edge set among the nodes is defined as E . The variable value is a finite number with a discrete value. The directed edge among the nodes constitutes the directed acyclic graph $G=\{V, E, P\}$. Each variable node X_i and its father node set W_i correspond with the conditional probability table $P(X_i | W_i, G)$. Thus, the joint probability distribution table can be expressed as:

$$P(x_1, x_2, \dots, x_n) = \prod_{i=1}^n P(x_i | w_i, G) = \prod_{i=1}^n P(x_i | x_{i-1}, \dots, x_1). \quad (1)$$

Bayesian' formula can be expressed as:

$$P(X_i | D) = P(X_i, D) / P(D) = P(X_i)P(D | X_i) / P(D). \quad (2)$$

$P(X_i)$, $P(D | X_i)$, can be obtained through expert advice and literature research, and $P(D)$ can be inferred by the joint conditional probability.

The target of specific problem is under study. The object of study and the characteristic variable set included in the object are determined to correspond with the node set in the Bayesian network. In terms of the occurrence characteristic of the transportation accidents of dangerous chemicals, the incentives influencing the accidents are determined, mainly including the direct cause of the accident and the indirect incentives of management. Therefore, all of these factors are set as a node-set of influencing factors of the accidents, and the Bayesian network is established, as illustrated in Figure 3.

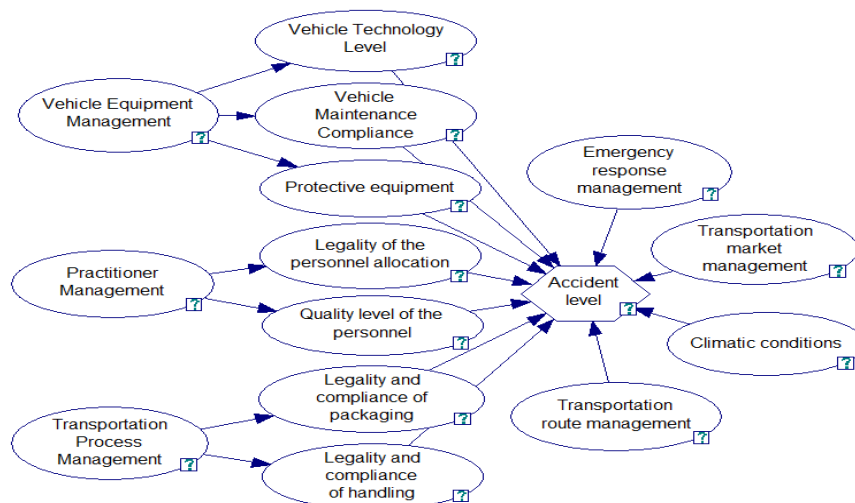


Figure 3. The experience diagram.

4.2 Structure Amendment and Parameter Learning of the Bayesian Network

In the above section, the structural equation model initially identifies the direct cause and the indirect cause of the transportation accidents of dangerous chemicals, as well as the causal relationship between them. Based on this, the Bayesian experience network is initially established. In the following sections, the topological graph of network structure is corrected through K2 algorithm. The experience network (Figure 3) is set as the background knowledge. The data learning results conducted on the basis of background knowledge are shown in Figure 5 (right), and the learning results without the reference of background knowledge are illustrated in Figure 4 (left).

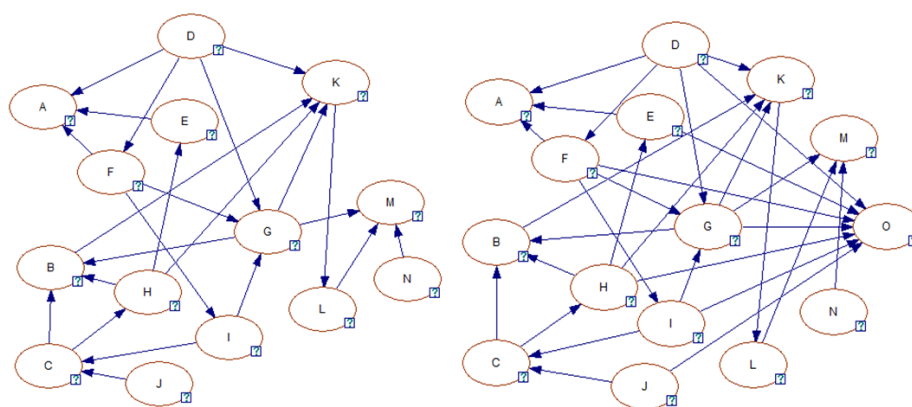


Figure 4.Amendment plan of data learning.

Cases of learning data are drawn from the Chemical Registration Center of State Administration of Work Safety in China, the labor disaster statistics website of Ministry of Medical Health and Social Security in Japan, domestic and foreign chemical accidents news on the China Aiweibang Website and related documents. Nearly 100 cases of transportation accidents of dangerous chemicals that happen at home and at aboard are collected, and the data is organized. The state nodes of transportation accident management of dangerous chemicals are set as discrete variables, and the possible values of variables are designed and the value range is given. The packing legality and compliance set is as: {yes=1, no=2}, and so on, as seen in Table 3. Furthermore, GeNIe 2.0 software is used to calculate the priori probability, as shown in Table 4. Algorithm K2 is adopted to calculate the posterior probability, as seen in Table 5.

Table 3 Value range of accident indicators

Management of special-purpose vehicles, equipment (A) Problem {Yes, No}	Vehicle technical grades (D) {transport vehicles of hazardous chemicals, transport vehicles of general cargo} Whether vehicle equipment maintenance is legal and compliant or not (E) {Yes, No} Response to environment protective equipment (F) {yes, no}
--	--

Management of transportation practitioner management (B) Problem {Yes, No}	Legality of personnel allocation (G) {Yes, No} Overall quality level of staff (H) {good, poor}
Management of transportation process (C) Problem {Yes, No}	Legality and compliance of packaging (I) {Yes, No} Legality and compliance of handling (J) {Yes, No}
Other management	Emergency rescue management: whether the emergency self-rescue of the enterprises is timely (K) {Yes, No} Transportation route management: the highway classification of transportation route (L) {expressway, national highway, provincial highway} Transportation market management: whether the transport enterprises are qualified to transport dangerous chemicals or not (M) {Yes, No}
Climatic conditions (N)	{Sunny, high temperatures, fog, snow }
Accident Level (O)	{No casualty, with casualty}

K2 algorithm is proposed by Cooper and Herskovits. According to the Bayesian Theorem:

(1) Score all the nodes one by one, and obtain a group of complete data in the entire network algorithm training.

(2) Set up the topological sorting of the network structure ρ and the number of upper limit of the parent node variables u , and search in accordance with the following rules.

$$\forall 1 \leq i \leq j \leq n, w_i \notin \{X_t | X_t \in W_i\}, 1 \leq t \leq n;$$

$$\text{score}(X_i, W_i) = \prod_{i=1}^n \prod_{j=1}^{q_i} \frac{(r_i - 1)!}{(N_{ij} + r_i - 1)!} N_{ij} \prod_{k=1}^{r_i} N_{ijk}! \quad (3)$$

$$P(D, B_s) = \prod_{i=1}^n \text{score}(X_i, W_i) \quad (4)$$

Wherein, N_{jk} represents the number of the father node W_i of the node X_i that is in the k th state; r_i indicates the number of the state of the node X_i ; the node N_{ij} is the total number of all the states of the father node W_i of the node X_i ; $P(D)$ represents the occurrence probability of data D , which is a constant regardless of the structure.

(3) Find the model with the highest rates

The starting point of the K2 algorithm is an edgeless graph that contains all the nodes and no edge. During the search, the variables in ρ are inspected one by one in order, the parent

node is determined, and the corresponding side is added. If the number of father nodes does not reach the upper limit u , the search continues. Until the CH score reaches the maximum, the search stops.

Table 4 Prior probability table

Vehicle Equipment Management	Practitioner Management	Transportation Process Management	Vehicle Technology Level	Vehicle Maintenance Compliance
0.3039	0.6667	0.2059	0.9314	0.7843
0.6961	0.3333	0.7941	0.0686	0.2157
Protective equipment	Legality of the personnel allocation	Quality level of the personnel	Legality and compliance of packaging	Legality and compliance of handling
0.9020	0.7647	0.7549	0.9020	0.8725
0.0980	0.2353	0.2451	0.0980	0.1275
Emergency response management	Transportation route management	Transportation market management	Climatic conditions	Accident level
0.6569	0.7282	0.3922	0.7596	0.7476
0.3431	0.1359	0.6078	0.1250	0.1748
	0.1359		0.0577	0.0777
			0.0577	

After the Bayesian network is decided, the posterior probability of each management factor can be inferred. If the prior probability of accidents is preset as 0.4, the management probability of no accident at high temperature is calculated, namely the posterior probability of management when $Q=2$, $R=1$, as shown in Table 5.

Table 5 The posterior probability table after learning

Vehicle Equipment Management	Practitioner Management	Transportation Process Management	Vehicle Technology Level	Vehicle Maintenance Compliance
0.3039	0.6667	0.2059	0.9848	0.9861
0.6961	0.3333	0.7941	0.0152	0.0139
Protective equipment	Legality of personnel allocation	Quality level of personnel	Legality and compliance of packaging	Legality and compliance of handling
0.9967	0.9667	0.9850	0.9917	0.9658
0.0033	0.0333	0.0150	0.0083	0.0342
Emergency response	Transportation route	Transportation market	Climatic conditions	Accident Level

management	management	management		
0.9697	0.6522	0.0476	0	1
0.0303	0.2029	0.9524	1	0
	0.1449		0	
			0	

5. CONCLUSIONS AND RECOMMENDATIONS

(1) Based on the hypothesis verification that there exists a causal relationship between the direct causes of the accidents and the management factors behind the accidents, the structural equation model is applied, and the accidents factors of humans, vehicles and environment are classified corresponding to the loopholes of the management factors. The results show that the management factors has made significantly indirect effects on the occurrence of accidents.

First, the influence path coefficients of the internal safety management of dangerous chemicals transportation enterprises on the practitioner management and vehicles and facilities management are 2.2247 and 0.261, indicating that the enterprises are in charge of the first-line obligation of personnel, vehicles, and equipment management. If the enterprises run loose operations on hiring employees and educational training, or on the implementation of the safety management procedures on the vehicles and facilities, it is highly possible to cause latent dangers of the accidents.

Secondly, the influence path coefficient of the industry management of dangerous chemicals transportation of the transportation sector on the practitioner management is 0.249, indicating that the competent transportation sector assumes unneglectable responsibilities for the practitioner management of dangerous chemicals transportation. Insufficient supervision and management of the enterprises, failed inspection of practitioner qualification and training directly lead to the occurrence of transportation accidents.

Thirdly, the influence path coefficients of the transportation management of dangerous chemicals of other departments on the equipment of vehicles and facilities and the emergency rescue management are 0.324 and 0.624, indicating that the industry management of other sectors undertakes the due obligations of safety supervision and management for the facilities and equipment used in the process of production, storage, usage, operation and transportation. Also, the departmental coordination concerning emergency rescue management is of particular significance. The establishment of an inter-connective accident information network and an monitoring network acts as an important means to improve the emergency response management, in order to effectively prevent secondary injury and to avoid greater losses.

(2) In order to investigate the importance degree and the changes of management factors when the accidents happen, the Bayesian network diagram is used to vividly describe the

mutual relationship between the process of accidents and the various reasons behind management. The network diagram is based on experience, and the accident cause system is converted to the management system. The management factors are set as the network nodes, and the value range of each node is limited. One-one mapping is established with the combination of accident data of online research. In the end, structure learning and parameter learning are conducted on the experience diagram to obtain the posterior probability of each management factor. The results indicate that, when no accidents happen at high temperature, the demands for vehicle operation and maintenance, quality level of the personnel and transportation management process tend to be higher. In addition, the change rates of the probability of personnel allocation, packaging, handling and emergency rescue are higher, which indicates that the accidents taking place during the transportation process of dangerous chemicals could not be ignored. The maintenance and the routine inspection of vehicle equipment, the protection measures of coping with the harsh environment, and the installation of emergency self-rescue disconnecting devices are important parts of preventing accidents.

First, in terms of transport management, the packaging and the loading of hazardous chemicals are not conducted in accordance with specifications. No successive inspection routine and other practices are arranged in the daily transportation. It implies the lack of standardization of the employment system for the practitioners, the shortage of educational training activities about skills and work safety, or the short of the formulation of clear and feasible operation specification for transportation procedures.

Secondly, from the aspect of vehicle equipment management, special tanks that are used to transport dangerous chemicals are illegally modified and aged. It implies that the enterprises do not carry out regular and comprehensive transport inspection and maintenance on the vehicles at fixed intervals, and vehicles in the industry management are not able to be scrapped, exited, recovered or supervised on time.

Thirdly, when it comes to cope with the environmental factors, there are no precautionary measures for the vehicles and the containers under special climatic environments like rain, snow, fog, haze, climates of ultra-high or ultra-low temperature, which reflects that no preventive measures are formulated for uncontrollable factors like weather and traffic that trigger the accidents. The lack of emergency response system and measures for hazardous chemical accidents indicates that no safety production hazards inspection and routine emergency drills are arranged.

6. REFERENCES

- Adedigba, S. A., Khan, F., & Yang, M. (2016). Dynamic safety analysis of process systems using nonlinear and non-sequential accident model. *Chemical Engineering Research & Design*, 111, 169-183.
- Baksh, A. A., Khan, F., Gadag, V., & Ferdous, R. (2015). Network based approach for predictive accident modelling. *Safety Science*, 80, 274-287.
- Bonvicini, S., & Spadoni, G. (2005). Hazardous material transport accidents: analysis of

- the d.g.a.i.s. database. *Environmental Health Risk* III, 131-140.
- BU Quan-min, & TONG Xing. (2014). Analysis on the reasons and response measures for accidents of dangerous chemicals transport. *Journal of North China Institute of Science and Technology*.
- Dong, Q., Qian, D. L., Li, C. H., & Fan, H. B. (2013). Research on safety evaluation indexes of the road transportation enterprise of dangerous goods. *Applied Mechanics & Materials*, 409-410(409-410), 1330-1334.
- Hu, J., & Cao, Y. (2015). Fuzzy Petri net based dynamic risk analysis of complex system considering protection layers. *International Conference on Fuzzy Systems and Knowledge Discovery*. IEEE.
- Kazantzi, V., Kazantzis, N., & Gerogiannis, V. C. (2011). Risk informed optimization of a hazardous material multi-periodic transportation model. *Journal of Loss Prevention in the Process Industries*, 24(6), 767-773.
- Khakzad, N., Khan, F., & Amyotte, P. (2015). Major accidents (gray swans) likelihood modeling using accident precursors and approximate reasoning. *Risk Analysis An Official Publication of the Society for Risk Analysis*, 35(7), 1336-1347.
- Kirytopoulos, K., Konstandinidou, M., Nivolianitou, Z., & Kazaras, K. (2014). Embedding the human factor in road tunnel risk analysis. *Process Safety & Environmental Protection*, 92(4), 329-337.
- Krejci, L., & Bambusek, M. (2012). Risk of the transport of dangerous goods by road transport in the Czech Republic. *Perner's Contacts*, 7.
- Liu, L., Sun, L., Li, J., Li, C., & Hu, X. (2012). An Approach to the Real-Time Risk Analysis for Hazardous Material Transportation. *Intelligent Decision Technologies*.
- Liu, L. P., Fan, T. J., & Xia, H. Y. (2011). Hazardous chemicals transportation risk control based on goal programming. *Advanced Materials Research*, 328-330, 751-754.
- Morteza Bagheri, Manish Verma, & Vedat Verter. (2012). An Expected Risk Model for Rail Transport of Hazardous Materials. *Transport of Dangerous Goods*. Springer Netherlands.
- Mou, R. (2010). Environmental risk assessment model on dangerous goods during transportation. *International Conference on Supply Chain Management and Information Systems (Vol.11, pp.289-294)*. IEEE.
- Qazi, A., Quigley, J., Dickson, A., & Gaudenzi, B. (2015). Evaluation of control strategies for managing supply chain risks using Bayesian Belief Networks. *International Conference on Industrial Engineering and Systems Management*.
- Qiu, S., Sacile, R., Sallak, M., & Schön, W. (2015). On the application of valuation-based systems in the assessment of the probability bounds of hazardous material transportation accidents occurrence. *Safety Science*, 72(72), 83-96.
- Schubert, M., Høj, N. P., Ragnøy, A., & Buvik, H. (2012). Risk assessment of road tunnels using bayesian networks. *Procedia - Social and Behavioral Sciences*, 48(2307), 2697-2706.
- Shishkina, E. D. (2015). Bayesian networks as probabilistic graphical model for economical risk assessment. *Xviii International Conference on Soft Computing and Measurements*. IEEE.
- Thierheimer, W., Tăne, N., Gruia, R., Gaceu, L., Thierheimer, D., & Ola, D., et al. (2010).

Risk arising from transport activities. *Environmental Engineering & Management Journal*.

Yang, N. P., Han, M., Chen, S. Y., Liu, X. H., & Kang, L. J. (2015). Research on evaluation method based on modified buckley decision making and bayesian network. *Mathematical Problems in Engineering*, 2015(7), 1-7.

Zhang, C., Chen, X., Chen, J., & Liu, Y. (2009). Risk assessment of dangerous chemical leakage with emergency response. *Journal of Tsinghua University*, 49(5), 621-624.