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Research on Safety Technology of Chemicals Transportation and Storage

Lisha Sun

Chongqing City Management College, Chongqing 401331, China
lasha@126.com

In the present study, In allusion to the problem that there is not systematically study on China's hazardous chemical transportation safety and management situation currently, based on abundant statistic and practical cases, and mathematical statistical analysis method was used to study the present hazardous chemical transportation safety's situation and main reasons, and based on a large number of investigation, our state's hazardous chemical materials safety management applicable laws and regulations, related functional department management duties were studied. In allusion to the problem that the risk for dangerous. chemicals transport problems are difficult to quantify, combined with the traffic accident studied the dangerous chemicals risk assessment indexes, at the same time the assessment method used to study the dangerous chemical transportation risk evaluation model and method. In allusion to the problem that the study of dangerous chemical transportation risk is not further enough, combined with this study's result--dangerous chemicals risk assessment method, China's dangerous chemicals transport risk points are analyzed, which established scientific basis for formulate safety management. Finally, from the point of perfect dangerous chemical transportation management system, strictly implement chemical transportation management responsibility, proposed some advice for dangerous chemicals transport safety management. This research results are dangerous theoretical basis of chemicals, transport for formulating safety management related system has vital significance.

1. Introduction

In recent years, our state's hazardous chemical materials traffic accidents showed high momentum which has already aroused the governments at all levels highly valued. Why there seems to have strict management system in the transport of dangerous chemicals and each transport links all seems under the condition of related department's strict supervision, but the security situation is so serious? Where is the key to solve dangerous chemicals transport safety problems? How to search the problem from different angles, and then through Principles of management with perfect system to administer the transport of dangerous chemicals (Zharova et al., 2017), make more safety, has important significance. The study targeted to grasp the macro-management, started from the implementation of the details management, based on a large number of practical research materials to carry out the research work (Li, 2011).
With the rapid development of the national economy and the chemical industry, hazardous chemicals in the promotion of industrial and agricultural production, meeting the needs of people's life and other aspects play an important role. The transportation of hazardous chemicals is increasing year by year, and the safety accidents of road transportation safety accidents also show a trend of increasing year by year. Because of the special nature of the hazardous chemicals, it is full of danger, and each link needs to be completed by transportation. Therefore, it should pay special attention to the safety management of every link in the process of hazardous chemicals transportation, and to prevent and contain the serious accidents (Lowther et al., 2008).
With the rapid development of chemical industry in our country, the demand of hazardous chemicals is increasing year by year. Since the places of origin and demand are different, a large number of hazardous chemicals are involved in off-site transportation (Okada et al., 2014). In the course of of transportation, a large part of hazardous chemicals in the liquid form are carried by road. As liquid hazardous chemicals are combustible, explosive and highly toxic, the vehicles carrying them on the road transport are forming a flow

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hazards. if there is an event of a leak or explosion, it will not only affect the traffic order, but also causes property loss, environmental pollution, even pose a serious threat to the life of the residents around the transportation routes. How to ensure the salty of liquid hazardous materials in road transportation, reducing the accidents risk, protecting the salty of residents aside the road and the environment, it is a topic of social concern and worth researching.

2. Safety technology of chemicals transportation

Firstly, the literature pertaining to risk assessment and optimal routing of hazmat transport by road is reviewed, and the current state and some questions of the art and theory and methodology used in previous hazmat transport management, risk analysis and optimal routing are identified. Based on the statistical analysis of typical hazmat transport accidents cases, the characteristics and rules of accidents are investigated as well as control countermeasure, and the route dependent risk factors and route independent risk factors are identified. Risk characteristics of transport hazmat are depicted by the hazmat average weighted risk rank and the modifying factors of accident-proneness (Jiang et al., 2012). On this basis, by identifying transport network, vehicles or travelling risk sources and accident impact areas, a new comprehensive systematic procedure to assessment hazmat transport risk is faced, introducing the modifying factors of accident-proneness and three kinds of risk enhancing or mitigating factors including intrinsic road characteristics, meteorological conditions, and traffic conditions (Wang et al., 2017). Furthermore, a route-oriented population risk and environment risk models and a rapid risk rating index approach are presented. The individual risk and societal risk models integrated with death probability coefficient of neighboring population along the hazmat route are analyzed, and the acceptability risk criterion on hazmat transport is discussed.

$$\Delta_{ij}(k) = \left|x_i(k) - x_j(k)\right|, k = 1,2,\ldots,n; j \in J = \{1,2,\ldots,m\} \tag{1}$$

Secondly, according to the above-described risk assessment technique and methods for hazmat during road transport, the essential meanings, figures, principles and methods of a risk-analysis-based optimal routing methodology are illuminated, and a new and general framework for optimal routing of hazmat transport and bi-level management mode between local government and carriers are brought forward. The benchmark of optimal routing problem is dependent on the exposure population risk along the road, and the assessment framework to determine the best path of hazmat transport by road is built, which includes hazmat attributes and classifies, road characteristics, impact population distribution, traffic environmental condition, emergency response capability, transport cost and so on. It is emphasized on the scale weighted technique of single objective routing and the Pareto optimal method of multi-objective routing. Moreover, the minimum hazmat accident probability path and the least population exposure path are searched by adopting impedance-adjusting node labelling shortest path algorithm and link labelling shortest path algorithm, respective (Snow et al., 2003). Additionally, the influence of weather condition on hazmat routing and the characteristics of hazmat accidents probability and impact population density varying with time are discussed, and a population risk model with time attribute is presented to search the minimum population risk at the best time. And the optimal routing of hazmat in time-varying, stochastic road transportation is also investigated deeply.

$$r\left(x_i(k), x_j(k)\right) = (min_i min_j min_k \Delta_{ij}(k) + \xi max_i max_j max_k \Delta_{ij}(k))/(\Delta_{ij}(k) = \xi max_i max_j max_k \Delta_{ij}(k)) \tag{2}$$

Thirdly, the case study for liquefied chlorine road transport in Tientsin region was systematically investigated, and quantified the release probability, catastrophic consequences, population risk, environment risk and other routing criterions, some of which were shown by the ArcGIS system (Bu et al., 2013). According to the above-proposed risk assessment and routing methods, the optimal routing for liquefied chlorine transport by road was determined, and it reduced neighbouring population and environment risk for the used route. The case study suggests the route-oriented risk assessment model determine the risk level of hazmat during road transport well and truly, and the optimal routing methods based on the population risk along the used route decrease hazmat transport accidents frequency and catastrophic consequences and help the associated routing decision-making for hazmat.

3. Safety technology of chemicals storage

3.1 Chemical transport risk

Experimental results were presented in Figure 1. Choosing the road scientifically and reasonably is one of the most effective measures to reduce the risk of liquid hazardous chemicals transportation. Based on the above issues, as shown in Figure 1, the author of this paper takes route selection of hazardous liquid chemicals road transportation as the researching point. According to the characteristics of hazardous liquid chemicals, the author analyzes the possible risk and consequences, and emphasizes the leak and explosion risk particularly (Snow et al., 2006). Based on the risk assessment, it takes the risk expectations to measure the quantity of risk (Palanisamy et al., 2015). The model is constructed to meet the demand of the government and proof of the enterprise In this paper, there are two models: It only considers the risk factor in model I, and it considers the risk, cost and time factors in model II simultaneously (Stoessel, 2008). The model solution is given by the classical Dijkstra algorithm and Gray algorithm. Then an example proves that the model is feasible.

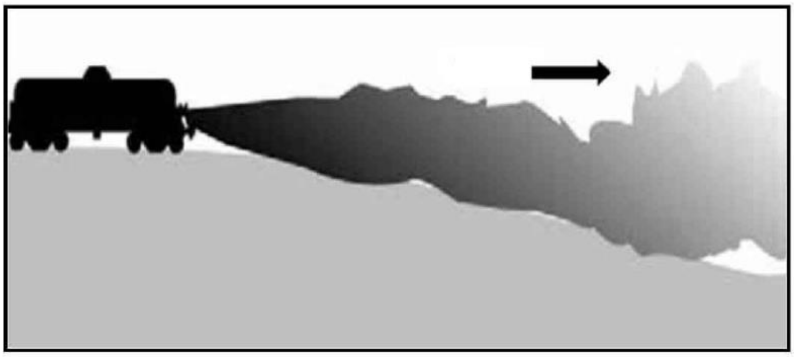

Figure 1: Chemical transport risk

Relative Weight and Consistency test. We use judgemental matrix to calculate relative weight coefficient and matrix eigenvalue of each index, as follow:

(1) Calculating multiplication of all elements in every row of the matrix $M_i = \prod_{j=1}^{n} a_{ij}$, where i=1,2, …, n, n is for the order of matrix;

(2) $\bar{W}_I = \sqrt[N]{M_i}$;

(3) $(\bar{W}_1, \bar{W}_2, \dots, \bar{W}_m)^T$ is normalized, $w_i = \bar{w}_i / \prod_{j=1}^{n} \bar{w}_j$;

(4) Calculating the characteristic root, $\lambda_{max} = \prod_{i=1}^{n} \frac{(BW)_i}{nW_i}$;

Single level sequencing and consistency checking. The above judgment matrix is appropriate? To check the consistency of the method is: Firstly we calculate the single level sequencing consistency index $\mathrm{C.I} = (\lambda_{max} - n)/(n-1)$. Then calculate the random consistency index C.R=C.I/R.I. If $\mathrm{C.R} \le 0.1$, we think that the consistency of the judgment matrix is acceptable, where the values of mean random consistency index R.I is determined from Table 1.

Table 1: The average random consistency index R.I

Dimension	1	2	3	4	5	6	7	8
R.I	0.00	0.00	0.58	0.96	1.12	1.24	1.32	1.41

We get fuzzy membership after feature vetors are normalized, and construct a fuzzy relation matrix R. General expressions of the fuzzy relation matrix for R:

$$R = \left(r_{ij}\right)_{m\times n} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}_{m\times n} \tag{3}$$

Where, r_{ij} is i fault determined as the evaluation set V_j(j=1, 2,...,n) membership, and membership degree vector index for i is $R^{(i)}[r_{1j}, r_{2j}, \dots, r_{nj}]$.

$$\mathrm{r}(x_i, x_j) = \frac{1}{n} \sum_{k=1}^{n} r(x_i(k), x_j(k)) \tag{4}$$

According to Eq.(3),. Evaluation vector:

$$Y = X \cdot R = (x_1, x_2, \cdots, x_m) \cdot \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = (y_1, y_2, \cdots, y_n) \quad (5)$$

In this paper, fuzzy synthesis operator "·" use summation operation of the multiplication and the limit of 1, i.e. the weighted average value, finally getting the fault reason fuzzy vector, determining the cause of failure. After the fuzzy operation, we obtain fault reason fuzzy vector Y=(y_1, y_2,..., y_n), and set a threshold level $\gamma \in [0,1]$, remembering O=max(y_1, y_2, ..., y_n). If $0 > \gamma$, the diagnosis is feasible, otherwise the sign vectors provide inadequate, we should add information to re-diagnosis. Threshold γ is mainly determined by experts real-time adjustment according to the actual situation in order to improve the diagnostic accuracy.

3.2 The simulation process

The membership function in fuzzy theory and fuzzy relation matrix describe the relationship between fault phenomenons and fault causes, and provide the scientific basis for the diagnosis of auto fault and repair method.

There are two domains, with the factors U represent the fault phenomenon domains, evaluation set V represents the failure domain, and the fault phenomenon membership derive fault membership. With a diagnosis of object has n fault, may be expressed as y_1, y_2,···,y_n, m fault phenomenon caused by the failure, can be expressed as x_1, x_2, ···, x_m.

Therefore, fault fuzzy vector:

$$Y = (y_1, y_2, \cdots, y_i, \cdots, y_n) \quad (6)$$

Where, y_i(i=1, 2, ..., n) is the membership of fault reason y_i.

Fault phenomenon fuzzy vector:

$$X = (x_1, x_2, \cdots, x_i, \cdots, x_m) \quad (7)$$

Where, x_j(j=1, 2, ...,m) is the membership of fault phenomenon x_j.

The commonly used methods for determining the membership are fuzzy statistical method, assignment method, contrast sequence method, using existing "yardstick" etc..

The basic idea is to determine on a domain whether x from elements belong to a domain of a variable clear set A. Fixed elements x in the fuzzy statistical test, practice has proved that show a membership frequency stability with the increase of n value, frequency stability values become the membership of x on A, i.e.:

$$A(x) = \lim_{n \to \infty} \frac{number \quad x \in A}{n} \quad (8)$$

This method is generally considered as a subjective method. It can bring people's experience into consideration. Assignment method is to apply some forms of fuzzy distribution according to the nature of the problem, then determine the parameters of the distribution according to the measured data.

Contrast Sequence Method. It is difficult directly to describe the membership between the vehicle fault reasons and fault fuzzy sets. By contrast, it is easy to identify two corresponding membership degree. We can obtain the membership function by orting, processing and mathematical method.

In the Social Sciences, we can directly use existing scale as the membership degree of fuzzy sets.

The vehicle state is progressive and sporadic. Progressive changes rule show that vehicle technical condition varies monotonically with use time or mileage, then it can be described by n polynomial or exponential function. In this process, the vehicle is not completely intact, is not entirely the fault, but in the middle of a state, the same sign. We determine the fault phenomenon membership by the semantic description, as shown in Table 2.

Table 2: Fault phenomenon membership values

Fault phenomenon feature	Normal	Slight	Usually	Serious	Very serious
Membership value	0.0-0.1	0.1-0.3	0.3-0.5	0.5-0.8	0.8-1.0

Figure 2: Leak site proliferation instances.

For example as shown in Figure 2, a vehicle fault phenomena appeared as: burnt flavor is pungent, engine sound slightly abnormal, and the wheel does not appear jitter, according to the driver description, we get quantization to the driver's fuzzy answer fault phenomenon vector (0.7, 0.2, 0). Distance from the shortest schematic was listed in Figure 3.

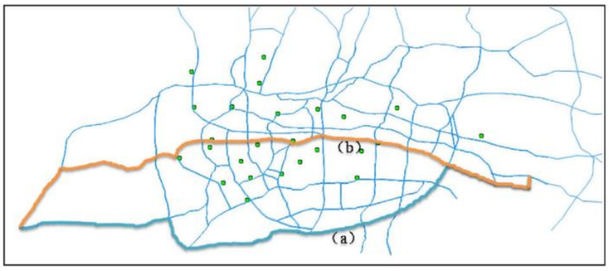

Figure 3: Distance from the shortest schematic.

The shortest time result was shown in Figure 4, we analysed the models and algorithms commonly used in optimal routing, and established multi-objective optimal routing models using the Fuzzy Neural Network and Analytic Hierarchy Process. Finally, we did a case study of butadiene road transportation in Guangzhou, made a quantitative assessment of the leakage rate, casualty risks and environmental damage risks of butadiene transportation. We carried on single-objective optimal routing simulations including shortest time, least casualty, minimal environmental damage and best emergency capability, analyzed the differences of different routing results. Finally we realized the multi-objective optimal routing based on the Fuzzy Neural Network and Analytic Hierarchy Process by adopting ArcGIS platform, ALOHA simulation software and MATLAB software, and put forward some suggestions on the topic of methanol materials route optimization, path line banning policy and construction of emergency response facilities as shown in Figure 4.

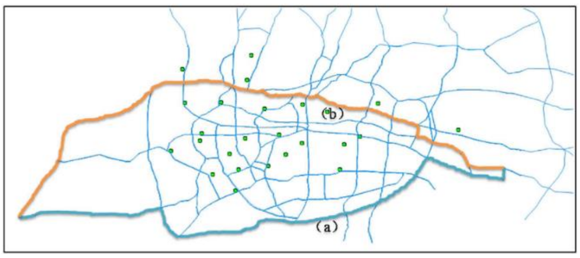

Figure 4: The shortest time.

4. Conclusion

In recent years, China's economy continues to develop, construction, petroleum, chemical industry and other industries gained fast development. Dangerous liquid chemicals act as an increasingly important role acting as industrial raw materials. On the one hand, dangerous liquid chemicals transport industry has entered a stage of rapid development, on the other hand, safety management problems has been discovered by studying the dangerous properties and frequent accidents. In this paper, the safety management of hazardous chemicals transportation in China in recent years is introduced, and the research object is carried out. Based on the summary and study of the situation and problems, this study analyzes the general problems existing in the safety management of dangerous chemicals Road Transportation and the causes of these problems. At the same time, based on the 4R crisis management model of Robert Heath, this paper puts forward some concrete suggestions, hopes to strengthen and improve the safety management of dangerous chemicals Road Transportation in our country.

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