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Safety Analysis and Countermeasure of Tank Car Transportation Based on Fish bone Diagram and Analytic Hierarchy Process

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Abstract. Tanker transportation is an important part of road transportation of refined oil. Compared with other modes of transportation, it has high risk and is prone to accidents, which not only promotes economic prosperity, but also affects public safety and social stability. Therefore, analyzing and exploring the main factors affecting the accident of tank trucks and preventing the secondary occurrence of similar accidents is of great significance of improving transportation safety and promoting social stability and economic development. Taking specific accidents as an example, this paper analyzes the causes of oil tank accidents from the perspective of system safety and puts forward some specific suggestions.

1. Introduction

The traffic accident rate of China's oil transportation industry is increasing day by day. Various oil tank fire accidents occur from time to time, which not only causes huge economic losses to people, but also poses a great threat to people's personal safety. Therefore, for the characteristics of these accidents, we need indepth analysis and research the hazards and the risk factors that cause accidents.

2. Analysis of tanker accidents

2.1 Characteristics of the tanker accident

(1) The time of the accident is uncertain

Explosive combustion of tank trucks usually has a short time, a sudden and instantaneous explosion, no obvious aura before the explosion, and explosion and combustion alternate, so the time of the accident is uncertain.

(2) The location of the accident is liquid

As a fuel transportation equipment, tank trucks have different conditions and risk factors of different regions during transportation. Different environmental conditions in different places also make the accident site fluid.

(3) The accident is very harmful and it is difficult to save

The refined oil has good fluidity. Once it leaks from the tanker, it will easily spread over a large area. When exposed to specific external conditions such as wind direction, wind speed, temperature, etc, the fire will rapidly expand and spread around. This kind of fire has high energy and high radiant heat, making it difficult to save. In addition, the container in the fire site is in danger of being exploded by heat, and the toxic and harmful substances produced by burning will be poisoned if inhaled by a large number of people.

2.2 The danger of tanker accidents

Tanker transportation Because the loaded oil is flammable, explosive, and toxic, there is a high possibility of accidents such as fire, leakage, explosion, etc. It is a "dangerous source of movement", driving or riding a tanker Personnel, citizens passing by tank trucks, buildings and personnel near the road passing by during transportation may become victims of accidents, and dangerous goods transportation accidents belonging to tanker transportation are characterized by sudden and frequent occurrences. The consequences of an accident are often extremely serious.

3. System safety analysis of tanker accidents using fishbone diagram

At 4:20 pm on June 29, 2012, the Guangzhou-Shenzhen Expressway from Guangzhou to Shenzhen was in the rear of the Nangang section of the viaduct. The truck and tanker rear-end accident occurred, causing the explosion to burn, affecting the cargo yard and work shed below and near the viaduct. After the construction, the fire area was about 1400m2, which eventually killed 20 people, injured 31 people, and directly damaged more than 10 million yuan.

The basic situation is that the tanker parked on the high-speed road and was chased by a rear truck, causing the tail of the tanker to rupture and the solvent oil inside to leak. At 5:16 pm, the explosion area under the viaduct bridge exploded and the flame rose upwards, and then spread to nearby work sheds and other buildings.

From the perspective of system engineering, the main factors of accidents in tank trucks can be divided into four major points: people, equipment, environment and management, including human, material and management. Human factors, including people's work attitudes, skill mastery, and work behavior. The factors of the product, namely the composition of the finished oil itself, the structure and stability of the components of the oil; the handling and transportation tools used in the transportation process, and other related facilities and equipment. Management factors refer to the formulation and implementation of regulations and systems that need to be done in the course of work; safety management institutions and mechanisms; safety supervision and assurance.

3.1 human factors

There are mainly non-implementation of work procedures and improper handling of personnel. The operation procedures are not implemented and include improper operation, poor safety awareness, poor sense of responsibility, unfamiliar fire fighting skills, unreasonable parking location of tankers, and no warning signs for loading and unloading. Personnel should deal with improper handling, including failure to take timely fire-fighting measures. Timely evacuation of surrounding personnel, failure to isolate leaked oil products in time.

3.2 Equipment factors

Equipment issues include gas station equipment and tanker equipment issues. Gas station equipment problems include insufficient sandboxes for fire extinguishers, sandboxes for fire retardant, too long a fire extinguisher configuration, grease gun leaks, aging of fueling equipment, etc. Tanker equipment problems are not equipped with fire extinguishers, tank corrosion leaks, tanker parts Aging and so on.

3.3 Environmental factors

Environmental factors include the gas station layout environment and the tanker transportation route environment. The gas station layout environment problems are arranged in the downtown area, and there are other hazardous chemicals bases nearby. The transportation environment problems of tank trucks include traffic congestion, heavy roads, complicated road conditions, dry weather and wind.

3.4 Management factors

Including security inspections is not implemented and accident prevention is not in place. Failure to implement safety inspections includes failure to implement leadership responsibilities, no rewards and penalties, inspections in the form, poor management of fire-fighting equipment, inadequate management and maintenance of fueling equipment, etc. Accident prevention does not include emergency plans for handling accidents, and no accident drills. There is no safety training for staff. The fish bone diagram is shown in Figure 1:

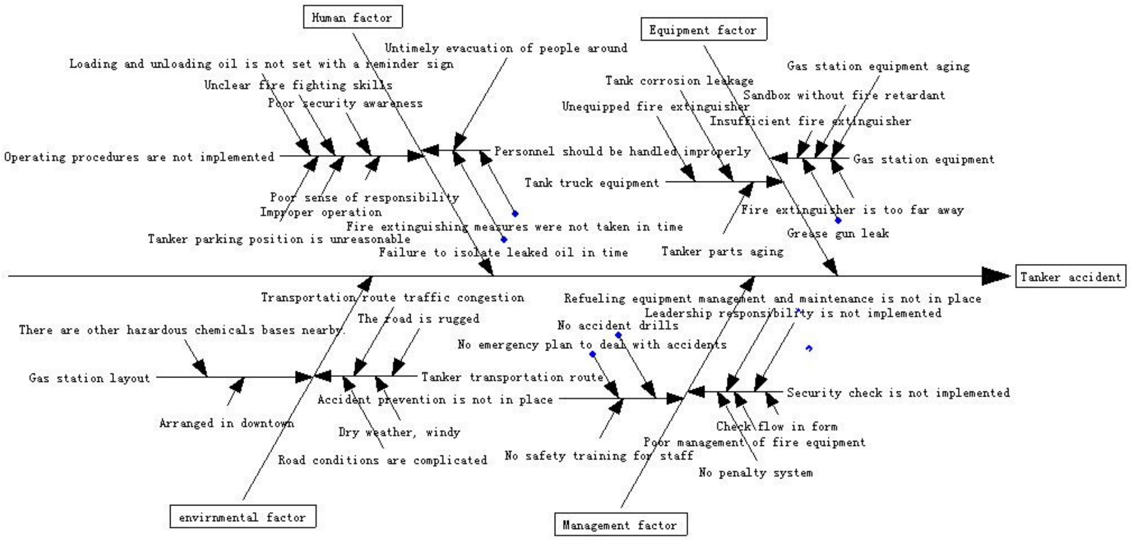

Figure 1 Tanker accident fish bone diagram

4. System safety analysis of tanker transportation processes using analytic hierarchy process

Analytic Hierarchy Process (AHP) is a systematic analysis method proposed by American operations researcher TL Saaty in the mid-1970s. This method can decompose complex systems into different levels such as target layer, criterion layer and scheme layer. Decision making for qualitative and quantitative analysis. It stratifies, quantifies, and models human decision-making processes, providing quantitative mathematical basis of analysis and decision-making. This is an effective method of quantitative analysis of non-quantitative events, especially when the structure of target factors is complex. This approach is very useful when you need to quantify the experience of a decision maker when there is a lack of important data.

The analytic hierarchy process is applicable to the analysis and decision-making of multiple criteria, multiple objectives or problems without obvious structural characteristics. It is widely used in management evaluation, economic development comparison, resource planning analysis, accident cause analysis, personnel assessment and economic security analysis.

4.1 Basic steps of the analytic hierarchy process

When modeling with AHP, there are generally the following four steps:

1) Establish a hierarchical structure model;
2) constructing a judgment matrix;
3) Calculate the weight vector;
4) Consistency tests.

4.1.1 Establishing a hierarchical structure model

Analyze the factors involved in the problem and their interrelationships, and divide these factors of several levels from top to bottom. Each factor of the same layer belongs to the upper layer or to the upper

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layer, and controls the next layer or is affected by the lower layer. The hierarchy can generally be divided into: target layer/top layer, criteria layer/intermediate layer, measure layer/bottom layer.

4.1.2 Construction judgment matrix

After stratification, each factor of the same layer of each factor that influences or affects the upper layer is compared to pairs, and the degree of influence on the criterion is judged, and then quantized according to the scale specified beforehand to form a matrix, that is, a judgment matrix. The 1-9-bit scale is usually used to determine the values of the individual elements in the judgment matrix. These values are generally derived from expert assessments or empirical data.

4.1.3 Calculation weights vector

Calculate the relative weight of each factor of each judgment matrix for its criteria. By normalizing the feature vector W composed of the largest eigenvalues $\lambda_{\max}$ in the judgment matrix A, the ranking weights of the relative importance of the corresponding factors of the same level and a certain factor of the previous level can be obtained. The methods of calculating the weights include the summation method, the root finding method, and the exponentiation method.

4.1.4 consistency tests

In order to prevent the judgment matrix from being interfered by other factors, the judgment matrix is basically required to satisfy the consistency in the actual calculation, so the consistency check is performed. After passing the test, it can be proved that the judgment matrix is logically reasonable, and then the next result analysis can be performed. Judgment matrix consistency tests formula:

$$CR = CI / RI \tag{1}$$

Where CR is the consistency ratio. If CR < 0.10, the consistency of the judgment matrix can be accepted, otherwise the judgment matrix should be appropriately corrected. CI is a consistency indicator, which is calculated as follows:

$$CI = (\lambda_{\max} - n)/(n-1) \tag{2}$$

$\lambda_{\max}$ ---the largest eigenvalue corresponding to the judgment matrix;

n---the number of pairwise comparison factors;

RI---random consistency index, which can be determined by looking up the table, as shown in Table 1 below.

Table 1 Random consistency indicator RI values

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54

4.2 Determine evaluation indicators and establish a hierarchical structure model

From the previous fishbone diagram analysis, the factors affecting the safety of tanker transportation can be divided into four aspects: personnel factor, equipment factor, environmental factor and management factor. Target layer A: safety analysis of tanker transportation; criterion layer: B1 personnel factor, B2 equipment factor, B3 environmental factor, B4 management factor.

4.3 Construction judgment matrix and consistency test

Use the 1-9 scales method (see Table 2 below) to compare them separately. At the same time, according to the expert advice, judge the relative importance degree of each factor and correspond to the assignment. Use this method to construct all the judgment matrices of each level and perform the weight vector. Calculation and consistency check.

Table 2 Significance of the 1-9 scale

Scaling a_{ij}	meaning
1	C_i has the same effect as C_j
3	C_i is slightly stronger than C_j
5	C_i has a stronger influence than C_j
7	C_i is significantly stronger than C_j
9	C_i is definitely stronger than C_j
2.4.6.8	The intermediate value of the above two judgment levels
1.1/2.….1/9	The ratio of the effect of C_i to C_j is opposite to the above description.

The judgment matrix formed between A-B:

A	B_1	B_2	B_3	B_4
B_1	1	2	3	2
B_2	1/2	1	2	1
B_3	1/3	1/2	1	1/2
B_4	1/2	1	2	1

The eigenvalues are obtained by using MATLAB software:

$W=(w_1,w_2,w_3,w_4)=(0.424,0.227,0.122,0.227)$, $\lambda_{\max}=4.0104$.

$CI=\frac{\lambda_{\max}-n}{n-1}=\frac{4.0104-4}{4-1}=\frac{0.0104}{3}=0.003467$,look up the table, $RI=0.89$,

$CR=\frac{CI}{RI}=\frac{0.003467}{0.89}=0.003895<0.1$,and the consistency of the judgment matrix is acceptable.Therefore, the factors affecting the safety of tanker transportation are 0.424 for personnel, 0.227 for equipment, 0.122 for environmental factors and 0.227 for management.

5. Conclusions and related safety measure

According to the above, the most important factor affecting the safety of tanker transportation is the human factor (weight 0.424), the equipment factor (0.227) and the management factor (0.227) is the same as the secondary factor, and the environmental factor (0.122) is the last.

In combination with the above fish bone diagram and analytic hierarchy analysis, in order to avoid accidents as much as possible, it must be done: First, for tanker drivers, the performance of the vehicle should be strictly checked before each transportation, especially Braking performance, lighting function, etc, timely eliminate safety hazards. Secondly, the car safety equipment such as breathing valve, electrostatic device and fire extinguisher should be self-checked regularly, and the safety management personnel should actively cooperate with the relevant accessories to eliminate hidden dangers. The third is to carry out standard anti-leakage test for the oil inlet and outlet of the tank according to the safety parameters of the tanker, and accept the tank pressure check of the relevant safety personnel. The fourth is to carry out regular maintenance according to the mileage of the vehicle. The safety awareness of the fifth gas station staff should be improved. The relevant facilities and equipment in the station should be inspected regularly. If the equipment is found to be aging or damaged, or there are problems that may cause other safety hazards, it must be rectified immediately. At the same time, for the automatic control and remote control equipment of the oil station, there are also measuring instruments and other equipment, and the relevant staff are required to carry out regular inspection and calibration. Sixth, the oil pipeline should not use insulated polyethylene hose, and plastic containers should not be used for loading and unloading oil. Seventh, after the electrostatic grounding device is installed and installed, it is necessary to ensure that the position of the clamp and the magnetic connector is correct when the tanker is loaded with oil, to ensure that the device can play a true grounding conduction function, and to periodically check the electrostatic grounding protection device. Eighth, when selecting the location of the gas station tank area and the type of oil storage tank and accessories, it must ensure that all regulations are met and anti-static and lightning protection devices are installed. In addition, the organization and management of the gas stations tank area is also very important, to enhance employees' awareness of fire protection and to avoid the occurrence of artificial arson accidents.

All in all, accidents of tank trucks are affected by subjective factors and objective factors. To avoid accidents, drivers and gas station staff must work together to enhance their awareness of prevention, skilled professional skills, being familiar with operational rules and workflow, and master all kinds of oil hazards and accident emergency response methods, regularly check the relevant facilities and equipment, and immediately take reasonable and effective measures to improve the problem, enhance safety management, eliminate hidden fire hazards, and ensure the safety of loading, unloading, transportation and parking of tank trucks.

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