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A Literature Review of Hazardous Road Transport Risks and Coupling Evaluation

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***Abstract*—In order to better control the risks of hazardous road transport, this paper attempts to review the risk factors and risk coupling models of hazardous road transport, so as to provide theoretical basis and reference for the subsequent comprehensive identification and summary of risk factors of dangerous goods transportation and the construction of a more appropriate risk coupling evaluation model. Through the summary, it is found that the risks of hazardous road transport are generally divided into four categories: people, things, management and environment, and the more risk factors involved in coupling, the greater the coupling risk value, and the more subjective factors participate. The risk coupling evaluation model can choose between the N-K model and the capacity coupling model according to the sample data.**

***Index Terms*—hazardous road transport; risk coupling evaluation; N-K model; Capacity coupling model.**

I. Introduction

In recent years, the road transport of hazardous chemicals has shown a rising trend, and as of the first half of 2021, hazardous chemicals transported by road accounted for about 56% of the total transportation of hazardous chemicals, which is highly harmful and has alarge impact on society, so it is of great significance to control the transportation of dangerous goods. In order to control the risks of dangerous goods transportation more accurately, it is necessary to comprehensively identify and summarize the risk factors in dangerous goods transportation, build a more comprehensive risk factor index system, and introduce a more applicable risk coupling evaluation and prediction model to quantify various risk factors and bring them into the model for risk prediction, so as to prevent risks

II. Research Dynamics on the Risks of Hazardous Transport

Generally speaking, scholars generally divide the risk factors of hazardous road transportation into four categories: people, goods (including hazardous chemicals, transport vehicles and other equipment and facilities), pipes and environments, and each type of factor alone will bring greater transportation risks. For example, Grant Purdy [1] (1993) pointed out that driver factors can have a significant impact on hazardous road transport risks. Ambituuni [2] (2015) conducted statistics on 2318 dangerous goods transport accidents in Nigeria between 2007 and 2012 and found that 79% of accidents were caused by driver factors. Laijun Zhao [3] (2012) found through research that the three most influential factors in dangerous goods transport accidents are human factors, transport vehicles and facilities, and packaging and loading of dangerous goods. Xulei Wang [4] (2017) pointed out that human error is the direct factor with the highest degree of impact on accidents, while road conditions are the indirect factors with the highest degree of impact on accidents. Sahar Ghaleh [5] (2019) found that the main reasons for the increased risk of transport accidents of dangerous goods (oil) are the failure of the front and rear guards of the truck carrier, the failure of the brake system and improper inspection. Yuntao Li [6] (2020) found through research that the probability of an accident with a highway tanker truck and the subsequent consequences are highly dependent on different passing locations and environments.

For example, Bariha [7] (2023) found that during the loading and unloading process of LPG, its composition and weather conditions will bring safety accidents by affecting LPG vapor, gas diffusion and flammable distance. And most empirical studies show that the more risk factors involved in coupling, the greater the coupling risk value. In addition, Xiao Chen [8] (2019) found through empirical research that subjective factors (human factors and management factors) participate the most in the coupling process of road transport safety risks of hazardous chemicals, and cause greater risks. Ting Yang [9] (2019) found empirically that subjective and objective coupling risks are greater, among which human-loop coupling has the greatest risk. Jian Guo [10] (2023) analyzed the coupling risk of road transport of dangerous goods in coastal areas and found that the risk coupling of driver factors and road environmental factors has a high probability of accidents.

III. Research Dynamics on Risk Coupling Evaluation Models

A. *The application of the N-K model*

Xiao Chen [8] (2019) combined with 1047 hazardous chemical transport accidents in China from 2008 to 2014, and used the N-K model to calculate the probability of different risk couplings. Ting Yang [9] (2019) took 220 road dangerous goods transport accidents in China in the first half of 2017 as an example, and used the N-K model to calculate the coupling risk degree of the system. Cheng Luo [11] (2022) calculated the risk coupling degree based on 362 road transport accidents of hazardous chemicals in coastal areas of China from 2016 to 2020, using the newly constructed AHP-N-K model. Wencheng Huang [12] (2019) used the N-K model to calculate the risk coupling degree based on the statistics of railway dangerous goods transport safety accidents in China from 1985 to 2016. Jinfang Liu [13] (2022) used the N-K risk

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coupling model to quantify the coupling risk values under different coupling scenarios caused by railway dangerous goods transport accidents.

In addition, the N-K model is also widely used in various fields of risk coupling evaluation research, such as Fan Luo [14] (2011) used the N-K model to analyze the coupled risk of air traffic safety based on 519 air safety accidents. Xianguo Wu [15] (2016) based on 188 subway construction safety accidents, using the N-K model to calculate the risk value of different risk coupling in the subway construction process. Jinjia Zhang [16] (2017) calculated the coupling degree of gas explosion accident risk using the N-K model based on 437 gas explosion accidents. Wanguan Qiao [17] (2017) used the N-K model to measure the coupling degree of risk coupling of 375 major coal mine gas accidents from 2000 to 2014. Liwei Hu [18] (2018) used the coupling degree model and N-K model to calculate the coupling degree of single risk factor coupling and double risk factor coupling in highway traffic risk in plateau geological and meteorological environment, sample size data 6261. Jingyu Zhu [19] (2020) cited the N-K model to analyze the coupling risk of deepwater blowout accidents. Jia Wang [20] (2021) introduced the N-K model to the coupling study of safety risks in fruit and vegetable cold chain logistics. Huanxin Wang [21] (2021) constructed a coupling measurement model of marine traffic safety risk based on 719 maritime traffic accidents by using the N-K model, and calculated the occurrence probability and risk value of different risk couplings. Zengkai Liu [22] (2022) combined the NK model with a dynamic Bayesian network to quantify the coupling of submarine blowout accident risk.

B. *The application of the capacity coupling model*

For example, Junhong Chi [23] (2016) and Shiliang Shi [24] (2021) used the capacity coupling coefficient model and combined with AHP analytic hierarchy to quantify the obtained expert evaluation data and empower the indicators, so as to calculate the risk coupling degree of hazardous chemical road transportation. Ziheng Wang [25] (2020) combines the coupling degree model with Bayesian network to dynamically analyze the risk coupling of dangerous goods transportation.

In addition, the capacity coupling coefficient model has been widely used in other fields, such as Quanlong Liu [26] (2015) who used the capacity coupling model to measure the coupling degree between the risk factors of coal mine accidents. Fangxing Wan [27] (2017) evaluated the coupling risk of a deepwater oil and gas well transportation system in the South China Sea by drawing on the capacity coupling coefficient model and combining the entropy method to determine the weight. Shuhong Wang [28] (2018) evaluated the risk of multi-hazard coupling of comprehensive pipe corridors by using the concept of volumetric coupling and the coupling coefficient model in the field of physics. Yutong Xue [29] (2020) calculated the risk coupling degree of high-speed rail projects using the capacity coupling coefficient model and the expert evaluation method to obtain sample data. Ziqiang Guo [30] (2021) also cited the capacity coupling coefficient model when conducting the risk assessment of oil and gas pipeline landslide disasters, and calculated the risk coupling degree by introducing the coupling coordination function. Xinxin Zhang [31] (2020) also analyzed the human-factor coupling effect of maritime navigation accidents using a capacity coupling coefficient model. Jin Fu [32] (2022) used the capacity coupling coefficient model to comprehensively evaluate the risk coupling of cut-and-cover highway tunnels and adjacent subway collaborative construction.

C. *Application of other risk coupling models*

In addition to the above N-K model and the capacity coupling model, two more applied risk coupling models, there are also other risk coupling evaluation models, such as Gang He [33] (2016) with the help of structural equation model for coal mine safety risk causal coupling simulation. Yonghui Zhang [34] (2022) used Bayesian networks to quantitatively analyze the impact of different coupling effects between various risk factors of road transport on risk.

IV. Conclusion

Regarding the risks of hazardous road transport, scholars generally divide the risks of hazardous road transport into four categories: people, things (including hazardous chemicals, transport vehicles and other equipment and facilities), pipes and rings, and all kinds of risks alone may bring about greater safety accidents. Under normal circumstances, the occurrence of hazardous transport accidents is usually caused by the cross-action of some factors, and most scholars have found through research that the more risk factors involved in the coupling, the greater the coupling risk value, and the more risk coupling involved in subjective factors. Therefore, in the follow-up risk research on hazardous road transport in Hunan Province, we can refer to the classification methods and research results of the above literature, and summarize all the risks of hazardous road transport from the four aspects of people, things, management and environment.

As for the risk coupling evaluation model, the N-K model is the most quoted, followed by the capacity coupling model. N-K model has universal applicability and popularity in risk coupling analysis, but the model also has certain shortcomings, such as the model has high requirements for data integrity and sample size, and its calculation requires a large number of complete raw data, the sample size data in the above literature is generally large, the time span is large, and it is objective data, so the N-K model can be used. If the amount of data collected in the study is small, and subjective methods such as expert scoring or questionnaires are used, the model may not be suitable. The capacity coupling coefficient model has less strict requirements for data than the N-K model, and when the data collection adopts expert scoring and other methods, it is more suitable for the model, and most scholars tend to use AHP, entropy method and other methods to quantify the evaluation of experts and determine the index weight before referencing the capacity coupling coefficient model.

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