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A Review of Research Progress in the Last Twenty Years in Risk Management of Hazardous Materials Transportation

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Abstract: *Hazardous materials transportation incidents have become more common in recent years, resulting in significant deaths and property damage. Researchers and policymakers have been looking at the risk assessment of hazardous materials transportation for a long time. In order to better identify important concerns, researchers are studying the research development of risk assessment of hazardous materials transportation. This study examines the current literature on risk assessment models and methodologies of hazardous materials transportation from 2001 to 2020, and categorizes the relevant research based on unimodal and multimodal transportation systems. Furthermore, an example is used to analyses the features of each risk assessment model of unimodal transportation, and a unique thorough categorization for risk assessment problems is provided. The findings show that research on the risk assessment model of hazardous material road transport is extensive, but research on railway and intermodal transport is lacking. In comparison to the classic risk assessment model, the conditional value-at-risk model provides decision-makers with a flexible decision-making framework that adjusts risk preference between risk neutrality and risk aversion. Because of the difficulties of obtaining door-to-door railway transit and the additional hazards associated with intermodal transportation, the conclusion that the risk of railway and multimodal hazardous material transportation is lower than that of road transportation is not universal. Transport operators and governments can combine the benefits of many modes of transport, such as low risk, low cost, high flexibility, and high dependability, to accomplish public safety and increase system competency. This study outlines existing trends and research gaps based on the suggested categorization and summarises future research priorities.*

Keywords: *Transportation, Hazardous materials, Risk Assessment, Risk Model.*

1. INTRODUCTION

Hazardous materials (hazmat) are materials that are combustible, explosive, toxic, or radioactive. Mishandling of hazmat during transportation can result in combustion, explosion, leakage, and other incidents, posing a serious hazard to the public's personal, property, and environmental safety. This is the fundamental element that separates hazardous transportation challenges from other types of transportation problems. Over the years, the number of hazmat-related transportation incidents has grown. From January 2013 to December 2017, 356 hazardous transportation mishaps happened in China, resulting in 855 fatalities, 2980 injuries, and major emergency evacuations. This means that between 2013 and 2017, an average of 72 hazardous transportation incidents occurred per year. Numerous hazardous transportation incidents were reported worldwide in 2020. On June 13, 2020, a liquefied petroleum gas (LPG) tanker truck exploded in Wenling, Zhejiang Province, China, killing

20 people and injuring 172 others. On September 23, 2020, an oil tanker exploded in Lokoja, the capital of Kogi state in central Nigeria, killing at least 23 people and injuring many more. On November 16, 2020, a petrol tanker exploded on a highway in the Mexican state of Nayarit, killing 13 people, including the truck's driver. On December 16, 2020, an oil tanker disaster in Uttar Pradesh, India, killed at least 7 persons and wounded 25 others.

2. LITERATURE SURVEY

Several solutions have been offered in recent decades in response to the growing danger of accidents during hazardous transportation. Erkut et al. (2007) categorised the literature into four primary groups based on the study scope: (a) risk assessment, (b) routing, (c) facility location and routing, and (d) network design.

Leonelli et al. (2001) To reduce transportation costs, an optimum route selection technique based on risk analysis was presented. Most existing risk evaluation algorithms analyse the value at risk and choose the path with the lowest risk. Although this is a decent notion, it does not cover the expense of transportation. The minimum risk value typically suggests that transportation should avoid heavily populated regions and go through distant routes, which increases transportation time and expense. As a result, an optimal risk-cost path decision model should be developed.

Fabiano et al. (2002) created a common transportation structure model from origin to destination, and investigated transportation risk and route decision making. Because there are several risk assessment models for road transport, each with its own set of traits and flaws, the model chosen should be carefully studied.

Webster and Watson (2002). Initially, acceptable journals in the fields of transportation and risk analysis were chosen. Following that, a backward search was undertaken by citing pertinent literature. Finally, the contribution of the most useful item discovered in the previous stage was determined using a forward search. Using the aforementioned method, 272 items of literature were identified from 2001 to 2020. Figure 1 depicts the number of chosen publications published each year between 2001 and 2020. The graph shows that hazardous transportation research has advanced to a new level in the recent decade. The recent growth can be attributed to two factors: the primary research areas of hazardous transportation, such as risk assessment and routing problems, have maintained a consistent contribution, and the emergence of certain new problems, such as network design and toll setting, have rekindled researchers' interest.

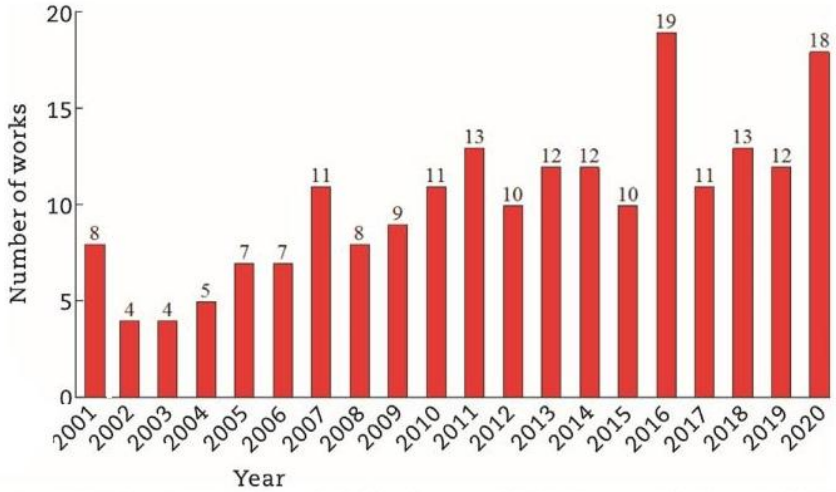

Fig. 1 – Number of works published annually between 2001 and 2020

Kara et al. (2003) A two-path optimization technique for reliable analysis of hazardous transportation hazards was suggested. Furthermore, as geographic information system (GIS) technology advances. During risk assessment, just one accident type and its adverse repercussions are often evaluated. The inflammability and explosive properties of hazmat dictate the variety of disaster kinds. As a result, a thorough hazard model of fire, explosion, toxicity, and other catastrophe

kinds must be established, and the weight of different accidents must be determined based on the varying probabilities of accidents.

Erkut et al. (2007) review focuses on hazardous transportation risk assessment issues. Although hazardous is typically transported by road and rail, it is also delivered via air, water, and pipeline. Unimodal transportation occurs when just one mode of transportation is used throughout the transportation process. Intermodal transportation occurs when various modes are considered or when the mode is changed throughout the process. Because the usage of various modalities varies so greatly, each one necessitates a unique risk assessment and modelling strategy.

Hassan et al., (2009) QTR is the evolution of QLR based on engineering technology and mathematical approaches, along with event consequence and frequency estimate. The aim of hazardous transportation research is risk assessment, which offers risk parameters and a decision-making foundation for transportation planning.

The literature for this review was collected by the structured search method proposed by

Wang et al., (2012) Hazmat risk may also be assessed in terms of time, which includes congestion, travel time, and emergency response time. This time-based hazardous transportation risk assessment is frequently related with toll policy and emergency management. A sensible toll policy can minimise traffic congestion and travel times. Furthermore, timely emergency response deployment can avoid future loss of life or environmental damage caused by accidents, hence minimising the repercussions. Most present risk assessment models only evaluate the population risk of accidents and do not account for environmental and property damage. As a result, the risk assessment has some limitations and is biassed. To calculate the entire risk of transportation, environmental risk and property risk models should be developed.

Bianco et al. (2013) reported a new integration trend of hazardous transportation that varies from the previously mentioned four categories and may be included independently. The majority of prior studies focused on risk assessment. Furthermore, scientific and reasonable risk assessment in the hazmat transportation process serves as the foundation for research on location selection, route optimization, and network design.

Bagheri et al., (2014). Although there is no comparable survey in China, intermodal transportation is frequently employed, such as PetroChina goods delivered by rail-road transportation and Sinopec LPG shipped by sea-land intermodal transportation. Because of the flexibility of short-distance truck transit, this is helpful to carriers. Furthermore, they benefit from the economies of scale associated with long-distance rail or sea transportation. As a result, various scholars have looked at the risk assessment of intermodal transportation. However, these studies largely compare the benefits and drawbacks of various modes of transportation, but systematic research on risk modelling of intermodal transportation processes is lacking. As a result, this study compiles and categorises the relevant literature on hazmat transportation risk assessment from 2003 to 2023. In addition, we discover a new thorough categorization for risk assessment situations. Through numerical examples, the properties and applicability of several risk assessment models are examined. Given the gap in existing research, this review outlines the issues of hazmat transportation risk assessment and suggests future research possibilities.

Pamucar et al. (2016) proposed a new cost and risk assessment method for the multi-objective selection of hazmat transportation routes on the urban road network. Finally, from other perspectives, several researchers established a framework for quantitative risk assessment.

Holeczek (2019) The majority of extant research focuses on unimodal transportation, such as road and rail. However, because to rising worldwide transportation demand, intermodal transportation is increasingly being employed in the transit of hazardous materials. In the United States, for example, 111 million tonnes of hazardous materials were moved via the intermodal transportation system in 2019.

Goforth et al. (2020) used GIS technology to propose a multi-objective program that facilitates the analysis and selection of minimally risky routes for hazardous waste transportation. Furthermore, in terms of influencing factors.

Li et al. (2020) proposed a real-time risk analysis method based on the fuzzy Bayesian network considering the transportation in an oil tanker, which dynamically reflects the changes in accident probability and consequence level of tanker transportation on roads.

Zhao and Ke (2021) established an optimization model to minimize the total cost and risk and evaluate the environmental risk caused by the location of explosive waste management facilities, inventory level, and multi-depot vehicle-routing.

Kara et al. (2022) proposed a two-path optimization algorithm for accurate analysis of transportation risks of hazmat. Moreover, with the development of geographic information system (GIS) technology.

Mazzarotta et al. (2023) However, the study of the risk assessment model for intermodal transportation exhibits systematic deficiencies. Typical intermodal transportation of hazmat includes short-distance connection, long-distance transportation, and intermediate reloading process. This indicates that the risks are affected by the transportation process and are associated with the reloading process.

3. SUMMARY

This document provides an overview of studies on hazmat transportation risk assessment issues that have been published in the previous 20 years. We review the literature on risk assessment models and hazardous transportation strategies. Furthermore, the benefits and drawbacks of various modes of transportation are weighed, and a new categorization for unimodal transportation is offered. The properties of each unimodal transportation evaluation model are examined using an example. Our research findings can be summarized as follows.

In recent years, there has been much study on the danger of hazardous road transport, with more than ten types of risk assessment models suggested, including TR, IP, and PE models. The risk assessment model of hazardous railway transport is built by adding railway transport features into road risk assessment models such as anticipated consequence, IP, and PE models. In terms of traffic volume and accident likelihood, railway and intermodal hazardous transportation are the lowest risk modalities. In the hazardous transportation decision-making process, transportation operators and governments can choose transportation options based on local conditions. However, research on multimodal transportation risk assessment is sparse and not systematic. To assess the applicability of a transport mode, an intermodal CVaR risk assessment model and a solution technique with adaptive risk preference must be established.

Furthermore, some issues in the construction of the hazmat transportation risk assessment should be addressed, which may be accomplished by taking three factors into account. One component is the examination of the use of unimodal and multimodal transportation. Based on the current study state, we discovered that after 2000, researchers usually agree that the danger of railway and intermodal transportation is lower than that of hazardous road transportation. However, because to the difficulties of obtaining door-to-door railway travel and the higher hazards involved with the intermodal reconfiguration process, this finding is not universal. As a result, analysing the use of unimodal and intermodal transportation systems may help government agencies and transportation operators make decisions. Furthermore, the benefits of many modes of transportation, such as low risk, cheap cost, high flexibility, and high dependability, may be integrated to accomplish public safety and increase system competency.

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