REVIEW THE HIERARCHY OF HAZARD CONTROLS TO URBAN ROAD SAFETY AND SUSTAINABLE MOBILITY

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***Abstract*—Governments globally have endorsed Vision Zero, declaring that no person should be killed or permanently injured on public roads. Concurrently, the wider social, public health, and environmental implications of urban structure and transport choices have gained intense policy attention, as cities aim to transition toward sustainable accessibility. This is especially the case as research reveals a range of counter-intuitive road safety dynamics; many narrow approaches to road safety management appear to trigger adverse risk compensation and negative externality effects, potentially running counter to broader sustainability goals. Recognizing the urgent need to integrate road safety with broader urban sustainability measures, this synopsis presents a review of road safety literature using the established Hazard Control Hierarchy. In doing so, we identify and categorize opportunities to more effectively combine Vision Zero with broader sustainable accessibility policy objectives. We synthesize the literature against the Hazard Control Hierarchy to devise a framework to more effectively integrate the work of professional disciplines which shape the safety and sustainability of the urban built environment.**

***Index Terms*—Road safety, Road transportation and Intelligent transportation systems**

I. Introduction

Urban road traffic accidents occur frequently due to various factors such as dense and diverse road bodies, highly concentrated road conflicts and complicated traffic environment.

With the continuous emergence of new urban construction concepts such as ecological cities, and safe cities, citizens' longing for a happy life is reflected. In urban construction, urban road traffic safety is a very important indicator. Therefore, constructing an urban road traffic safety risk evaluation index system that can both reflect the city's development direction and effectively prevent and control risks is important for the scientific and reasonable evaluation of urban road traffic safety risks, especially for reducing urban road traffic risks.

Hierarchy of hazard control is a system used in industry to prioritize possible interventions to minimize or eliminate exposure to hazards. It is a widely accepted system promoted by numerous safety organizations. This concept is taught to managers in industry, to be promoted as standard practice in the workplace. It has also been used to inform public policy, in fields such as road safety.[13] Various illustrations are used to depict this system, most commonly a triangle.

The hazard controls in the hierarchy are, in order of decreasing priority:

- Elimination
- Substitution
- Engineering controls
- Administrative controls
- Personal protective equipment

The priority should not be confused with effectiveness. The system is not based on evidence about effectiveness but based on the assumed burden on workers. If elimination of the hazard is possible, it frees workers of being aware of the hazard and protecting themselves. That is the basis for the priority. Substitution has less priority than elimination because the substitute can possibly also come with a hazard. Engineering controls depend on a well-functioning system and human behaviour. Administrative controls and personal protective equipment are always dependent on human behaviour which makes these controls less reliable.

II. RESEARCH MOTIVATION

Many researchers use a variety of methods and systems to increase road safety. Researchers are now using traffic simulation to figure out how intelligent transportation systems (ITS) affect road safety [3]. ITS is one of the most important technological systems in the field of transportation. Intelligent transportation systems are high-tech programs that help users learn more and use transportation networks in a safer, more coordinated, and "smarter" way by offering new services related to different kinds of transportation and traffic control. In fact, it was made by transportation engineers with the help of experts in fields like telecommunications and communications, electronics, computers, etc., using the information technology of intelligent systems [4]. Technology and science have grown a lot in the last few decades and are still improving. Also, with significant advances in artificial intelligence and hardware technologies, the performance of intelligent systems and their analysis have improved in many fields [2]. The ITS has improved safety and sustainable mobility by using technologies like measuring, analyzing, controlling, and communicating [5].

1. Intelligent Transportation Systems

There are numerous issues related to urban and rural management that have arisen because of the rise in the number of cars and the urban and rural populations, including the waste of time and money, the endangerment of drivers and pedestrians, and the air and water. Living standards continually decline while fossil fuel use rises. Meanwhile, the transportation sector has undergone significant transformation as a direct result of the rising need for mobility. The infrastructure of a country's transportation is now a big part of how its economy grows [5]. Intelligent Transport System (ITS) is one of the most important phenomena that has helped engineers and researchers in the transportation industry in the last few decades. Next-generation technology development in transportation engineering is often referred to as ITS. Nowadays, it's more crucial than ever to have a well-designed ITS.

III. Research Gap

Several valuable literature studies on ITS and road safety have been published. Some of them have been broad in scope, while others have concentrated on particular areas within ITS, such as the charging of electric vehicles, V2X communication, and a number of other mobility solutions. Many studies have been highlighted by these analyses and reviews. They have been rather successful in their analysis, giving just broad, overarching numbers of articles and the many subject areas covered. Even though these studies have shed light on the topic at hand, a more thorough evaluation of the ITS and road safety literature using rigorous bibliometric approaches might provide even more nuanced findings. Focusing on the intersection between road safety and ITS, this study provides a systematic analysis of the topic. This research began with a database of more than 10 published articles and narrowed it down to identify more significant works and investigators since "ITS" is a generic word that may apply to a wide range of papers. This study focuses on the depth and breadth of studies conducted over the last three decades.

1. Road Safety Hazards and Control Measures

Road safety hazards refer to road conditions or situations that can lead to accidents or injuries. This could be related to road design, user behavior, vehicle standards, or the surrounding environment. Control measures refer to ways of managing or eliminating these hazards.

Poor Road Design

This refers to poorly planned or maintained roads, lacking necessary signage or lighting, or lacking essential facilities such as pedestrian walkways or bicycle lanes. Control measures include conducting regular audits to identify and address such problems, installing effective signage to guide motorists, ensuring adequate lighting for night visibility, providing pedestrian and bicycle facilities, and incorporating calming measures like speed humps and roundabouts to slow down traffic

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Reckless User Behavior

Speeding, driving under the influence, failure to use seatbelts or helmets, and distracted driving (such as using a cell phone while driving) contribute to many road accidents. Stricter enforcement of traffic laws and regulations, public awareness campaigns to educate road users about the dangers of reckless behaviors, and employing technology like speed cameras and breathalyzers can help control such risks.

Vehicle Standards

Vehicles not meeting safety standards can be a potential hazard on the road, leading to mechanical failures and accidents. Regular vehicle inspections to ensure adherence to safety standards, stringent safety regulations for vehicle manufacturers, and promoting safety-enhancing technology like anti-lock braking systems (ABS) and electronic stability control (ESC) are effective control measures.

Surrounding Environment

Certain areas, such as uncontrolled intersections, school zones, and areas with high pedestrian traffic, can be hazardous. Installing traffic lights or pedestrian crossings, implementing school zone speed limits, and designing roads with safety barriers to separate different types of traffic can help mitigate these hazards.

IV. Driving Hazards and Control Measures

Driving hazards refer to threats or conditions that could lead to road accidents or unsafe driving situations. These may include weather conditions, other road users, the driver’s physical and mental state, road conditions, and vehicular issues. Control measures are the strategies or methods employed to mitigate these risks.

1. Weather Conditions

Certain weather conditions can greatly increase the risk of a car accident. Rain, snow, fog, sleet, and hail can reduce visibility and cause the roads to become slippery. Control measures include using appropriate lights, not just to see, but to be seen by other drivers. In conditions of reduced visibility, it’s important to slow down, as the stopping distance can be increased. If the weather conditions are too dangerous, avoid traveling until they improve. In snow or icy conditions, using snow tires or chains can increase traction and reduce the chance of skidding.

2.Other Road Users

Other road users, whether they are drivers, pedestrians, cyclists, or animals, can all present hazards. Defensive driving involves being aware of others, anticipating possible problems, and reacting in time. It involves following speed limits, keeping a safe distance from the vehicle in front, using mirrors and signals properly, and giving way to pedestrians at crossings.

3.Driver's Physical and Mental State

A driver's state of health and mind can greatly affect their ability to drive. Fatigue, distraction, and impairment from alcohol or drugs can slow reaction times and lead to poor decision-making. Regular breaks on long journeys can prevent tiredness. Mobile devices should be avoided when driving. Never drive when under the influence of alcohol or drugs, and if feeling emotionally unstable or stressed, it is better to avoid driving.

4.Road Conditions

Poor road conditions, such as potholes, loose gravel, or oil slicks can lead to a loss of vehicle control. Drivers should adjust their driving speed based on the road conditions and keep a safe distance from the vehicle in front. Hazardous conditions should be reported to authorities so they can be addressed.

Objectives

According to the main Objective of the regional disaster system theory, a disaster risk assessment idea based on the regional disaster system is proposed. At the same time, based on the analysis of urban road traffic safety risk index factors, a framework of urban road traffic safety risk influencing factors is proposed. And through the example verification, the risk index framework of urban road traffic safety is applied, and it is concluded that the risk evaluation ideas and risk index framework have certain scientific rationality.

Following objectives are perform future research work-

- Study of Road accidents linked to fog claimed.
- To analysis and side friction impacts on urban road links

V. Literature Review

Wiwiana Szalinska et al. [1] With the change of global climate and increased urbanisation, urban dry and hot hazards is becoming a more urgent problem that may affect sustainable city development. In the case of pronounced increase of air temperature and duration of dry periods, cities may experience long lasting heat waves, soil dryness, and water shortages that concern the urban population, ecosystems, and socio- economic sectors. The research investigates urban vulnerability towards compound dry and hot hazards in one of the largest Polish cities - Wrocław. The aim of the paper was the development of multi-hazard framework to establish a set of metrics for a hot and dry hazards monitoring system that would provide insights into better management and sustainable development of the city in the long run. The developed indicators and thresholds system for hazard assessment covers meteorological and hydrological drought indices, heat waves, long lasting dry spells, extremely hot days, cooling degree days and low flows identification procedures. Analysis of long-term variability of the indicators values including frequency and trend analysis were the basis for the estimation of hazard levels. The main socio-economic sectors were examined in terms of their vulnerabilities to dry and hot hazards with regard to the spatial variation of sensitive city components. A combination of the estimated hazard levels and the vulnerability of the respective city sectors supported with expert judgments provided a local multi-risks urban assessment matrix. Reducing risks of dry and hot hazards requires coherent actions including educational, organisational, and technical solutions.

David J. Ederer et al. [2] Based on the Hierarchy of Controls and the Health Impact Pyramid, we present a framework for prioritizing policies and interventions, known as the Safe Systems Pyramid, that contains five ascending levels – Socioeconomic Factors, Built Environment, Latent Safety Measures, Active Measures, and Education. The levels of the framework prioritize increased population health impact and decreased individual effort. Frameworks like "The 3 E's" emphasize collaboration rather than a change in thinking and action among transportation safety professionals, and do not prioritize specific actions. We argue that Vision Zero and other "Safe Systems" prioritize implementation of policies, programs, and infrastructure to increase population health impact by considering the individual effort necessary to obtain a protective effect.

Changkun Chen et al. [3] To assist the Department of Emergency Management in understanding the overall risk characteristics and situation of an urban agglomeration for a reasonable risk prevention and control strategy, this study developed a comprehensive multi-hazard risk assessment
model for an urban agglomeration with multiple factors. The proposed model includes disaster probability and disaster loss sub-models. The model evaluated four types of disaster risk in urban agglomerations: natural disasters, accidental disasters, public health incidents, and social security incidents. In addition, a variety of factors were integrated into the model, including the socioeconomic foundation of urban agglomerations, the oligopoly effect of core cities, historical disaster losses, the effect of disaster chains, the ability of disaster prevention and mitigation, and intercity coordinated rescue capabilities. Finally, the risk assessment model was applied to the Beijing-Tianjin-Hebei urban agglomeration. The assessment results were compared to the distribution of the new coronavirus pneumonia epidemic in the target urban agglomeration. The results showed that after analyzing the risk characteristics and evaluating the risk levels, the model not only showed the comprehensive risk levels and distribution of urban agglomerations but also revealed the high-risk areas and the key points of risk prevention and control. More importantly, the results obtained through the model can facilitate the strategic planning of disaster prevention and mitigation for urban agglomerations.

Quan Yuan et al. [4] Due to the increasing demand for goods movement, externalities from freight mobility have attracted much concern among local citizens and policymakers. Freight truck-related crash is one of these externalities and impacts urban freight transportation most drastically. Previous studies have mainly focused on correlation analysis of influencing factors based on crash density/count data but have paid little attention to the inherent uncertainty of freight truck-related crashes from a spatial perspective. While establishing an interpretable analysis model for freight truck-related accidents that considers uncertainty is of great significance for promoting the robust development of urban freight transportation systems. Hence, this study proposes the concept of freight truck-related crash hazard (FTCH) and employs the Bayesian neural network model based on stochastic variational inference to model uncertainty. Considering the difficulty of interpreting deep learning-based models, this study introduces the LIME model into the analysis framework to explain the results of the neural network model. This study then verifies the feasibility of the proposed analysis framework using data from California from 2011 to 2020. Results show that FTCHs can be effectively modeled by predicting confidence intervals for effects of built environment factors, in particular demographics, land use, and road network structure. Results based on LIME values indicate the spatial heterogeneity in influence mechanisms on FTCHs between areas within the metropolitan regions and alongside the freeways. These findings may help transport planners and logistic managers develop more effective measures to avoid potential negative effects brought by freight truck-related crash hazards in local communities. Ishita Dash et al. [5] Bicycling plays an important role as a major non-motorized travel mode in many urban areas. While increasingly serving as a key part of an integrated transportation demand management system and a sustainable mobility option, interest in biking as an active transportation mode has been unfortunately accompanied by an increase in the number of bike crashes, many with incapacitating injuries or fatal outcomes. Thus, to improve bicycling safety it is crucial to understand the critical factors that influence severe bicyclist crash outcomes, and to identify and prioritize policies and actions to mitigate these risks. Method: The study reported herein was conducted with this objective in mind. Our approach involves the use of classification models (logistic regression, decision tree and random forest), as well as techniques for treating unbalanced data by under sampling, oversampling, and weighted cost sensitivity (CS) learning, applied to bike crash data from the State of Tennessee's two largest urban areas, Nashville and Memphis. Results: The results indicate that random forest with weighted CS offers the potential for greater explanatory accuracy, an important observation given the paucity of efforts to date in applying random forest to bike safety studies. Inadequate lighting conditions, crashes on roadways, speed limits, average annual daily traffic, number of lanes, and weekends are the critical features identified. Conclusion: Based on these results, a series of specific, suggested policy changes are presented for implementation consideration.

Mazin AbdelMagid et al. [6] A critical component of transportation systems' resilience is their capability of withstanding disruptions and adapting to changing conditions to safely meet the demands of the users pre-, peri-, and post- disasters. Historically, disruptions from natural hazards are more consequential, with more negative disproportionate impacts on older adults, ethnic minority groups, rural, and disabled populations. Incorporating special users' needs as a core value of transportation systems resilience management will equip transportation agencies to improve the system performance for these populations. This study aims to expand the understanding of transportation systems resilience from an equity standpoint. To achieve this, two sets of surveys were used to collect data about the vulnerable populations' needs and concerns, and a conceptual framework connecting the users' needs to the system's performance was developed. The paper proposes a planning framework for transportation agencies to improve the transportation system's outcomes for vulnerable communities, with a particular focus on resilience to natural hazards. Overall, the results underscore the critical role of user input in achieving equity in resilience planning by providing a formal mechanism for integrating the specific needs of vulnerable populations into the planning process. Contributions to resilience and engineering management literature are achieved by highlighting the shortcomings of current resilience approaches and providing a framework for the formal incorporation of vulnerable populations' needs in the agencies' documented plans for the purpose of improved resilience management.

Emily Gemmell et al. [7] Urban environments influence child behaviours, exposures and experiences and may affect health, development, achievement and realization of fundamental human rights. We examined the status of eleven UN Convention on the Rights of the Child articles, in a multi-case study across four global cities. Within all study cities, children experienced unequal exposure to urban environmental risks and amenities. Many violations of child rights are related to car-based transportation systems and further challenged by pressures on urban systems from rapid population increases in the context of climate change. A child rights framework provides principles for a collective, multi-sectoral re- imagination of urban environments that support the human rights of all citizens.

Naim Kapucu et al. [8] As the scale and intensity of disasters continue to increase, building and enhancing resilience to disasters has become a critical policy and governance issue. This topic is crucial to urban infrastructure resilience because infrastructure systems support the continuity of operations of governments and businesses, and are essential to the economy, health, and public safety. This paper proposes and applies a network governance perspective to examine interdependent infrastructure systems, such as water (wastewater), electric power, transportation, and telecommunication. The paper contributes to a better understanding of the role of interdependent infrastructure systems in enhancing urban infrastructure resilience to disasters. The paper also highlights the need to leverage collaborative leadership and organizational capacity to develop robust and connected community networks to enhance urban infrastructure resilience to disasters.

Yiping Bai et al. [9] With the rapid urbanization and development of China, urban utility tunnels (UUTs) that combine various city lifelines are developing quickly. However, along with the convenience brought by UUTs, these concentrated lifelines also create more potential hazards. To overcome the shortage of traditional hazard identifications and match the characteristics of UUTs, the EPE model (Energy transfer theory - Preliminary hazard analysis - Evolution tree) is proposed in this paper. Based on the EPE model, a series of well-organized hazard lists of UUTs are presented, including 189 hazards in 28 categories, covering common hazards, specific hazards and risks of multi-hazards of UUTs. Following the identification of worst-case accident scenarios, a comparison analysis of UUTs and traditional pipelines is performed. Moreover, several practical suggestions regarding long-term planning, durability, classification and regulation of UUTs are proposed. This research may be helpful to establish safer, more coordinated and efficient UUTs to facilitate city life. Monica Santamaria-Ariza et al. [10] Transport infrastructure systems (TIS) are key enablers of economic development and welfare. However, such infrastructures are exposed to natural and anthropogenic hazards that have caused structural failures, traffic disruptions, injuries and fatalities, and damages to the environment. These past events have underscored the need for more resilient transportation systems. However, reducing risks and achieving more resilient infrastructure systems may result in greater resource consumption and environmental impacts, demanding the consideration of sustainability requirements in the management of TIS. Therefore, this paper conducts an exploratory study to map the current knowledge in the domain of risk, resilience, and sustainability management of TIS. As a first step, the system identification of TIS in the context of their management is conducted for the purpose of providing the basis for searching for relevant information. This step sets the baseline for conducting a bibliometric analysis of 16,395 scientific works extracted from the Scopus database between 1990 and 2022. Two quantitative bibliometric techniques are used, namely term co-occurrence and bibliographic coupling.

VI. Conclusion

Because most criteria are not assigned to only one sustainability dimension in the existing literature, future works on the subject should pay particular attention to the tradeoffs between the criteria. The discovery of tradeoffs between criteria is a very important topic for future research. Theories and the practical implications of these discoveries deserve special attention. While it comes to sustainability, competing agendas are another key aspect to consider when delivering new solutions for transportation inside business ecosystems, including a variety of partners from a wide range of companies. weight that different actors put on certain sustainability criteria may vary. Another subject worthy of inquiry is the identification of such disputes and how they may be resolved. To sum up, transportation is one of the most important factors in reducing the negative effects of climate change.

References

[1] Szalińska, W., Otop, I., & Tokarczyk, T. (2021). Local urban risk assessment of dry and hot hazards for planning mitigation measures. Climate Risk Management, 34, 100371.

[2] Ederer, D. J., Panik, R. T., Botchwey, N., & Watkins, K. (2023). The Safe Systems Pyramid: a new framework for traffic safety. Transportation research interdisciplinary perspectives, 21, 100905.

[3] Chen, C., Zhao, D., He, F., & Sun, F. (2023). A comprehensive multi-hazard risk assessment model for an urban agglomeration with multiple factors. Journal of safety science and resilience, 4(1), 43-51.

[4] Yuan, Q., Lin, H., Yu, C., & Yang, C. (2023). Modeling freight truck-related traffic crash hazards with uncertainties: A framework of interpretable Bayesian neural network with stochastic variational inference. International Journal of Transportation Science and Technology.

[5] Dash, I., Abkowitz, M., & Philip, C. (2022). Factors impacting bike crash severity in urban areas. Journal of safety research, 83, 128-138.

[6] AbdelMagid, M., AbdelRazig, Y., Smith, D., Horner, M., Choi, J., Kim, K., & Ventimiglia, B. (2023). Transportation system performance capabilities for vulnerable populations. International Journal of Disaster Risk Reduction, 96, 103991.

[7] Gemmell, E., Adjei-Boadi, D., Sarkar, A., Shoari, N., White, K., Zdero, S., ... & Brauer, M. (2023). “In small places, close to home”: Urban environmental impacts on child rights across four global cities. Health & place, 83, 103081.

[8] Kapucu, N., Hu, Q., Sadiq, A. A., & Hasan, S. (2023). Building urban infrastructure resilience through network governance. Urban Governance, 3(1), 5-13.

[9] Bai, Y., Zhou, R., & Wu, J. (2020). Hazard identification and analysis of urban utility tunnels in China. Tunnelling and Underground Space Technology, 106, 103584.

[10] Santamaria-Ariza, M., Sousa, H. S., Matos, J. C., & Faber, M. H. (2023). An exploratory bibliometric analysis of risk, resilience, and sustainability management of transport infrastructure systems. International Journal of Disaster Risk Reduction, 104063.