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# Railway Safety Perspectives: Trends, Concerns and Future Directions

[1]Atul Sarojwal, [2]Akriti Garg, [3] Mukul Kumar Singh, [4]Ashish Kumar Sankhwar

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**Abstract—** Rail transport has significantly transformed human mobility, and with its continuous development, the focus on train and infrastructure safety—particularly concerning passengers—has become increasingly critical. This paper examines the various methods adopted to ensure high levels of safety in railways through an extensive review of existing literature. A total of 48 relevant articles were shortlisted for in-depth analysis, combining bibliometric research with a comprehensive literature assessment to evaluate current safety management practices in the railway sector. In recent years, high-speed rail systems have drawn considerable attention from experts and railway authorities due to their higher risk potential. Consequently, numerous advanced technologies, supported by artificial intelligence and machine learning, are being developed worldwide to guarantee consistently high safety standards. Among the most sensitive areas are railway stations, especially platform zones, which represent critical hotspots for accidents, including suicide incidents. Various preventive strategies have demonstrated measurable improvements in safety, reinforcing railways as one of the safest modes of transport infrastructure. Building on these advancements, the application of resilient safety models could further strengthen safety performance and ensure more robust protection for passengers and operations.

***Keywords—*** *Safety, Railway, Station, Train, Literature review, Accidents*

## 1. INTRODUCTION

Railways represent one of the principal modes of transportation worldwide, serving short-, medium-, and long-distance travel. Over time, scientific research has increasingly concentrated on enhancing both the speed and safety of train operations. This paper highlights the critical issues affecting the global railway network—an area that has drawn considerable international attention due to its direct connection to public safety and economic performance. Several major factors contribute to railway safety risks. Collisions often occur at level crossings between rail tracks and roadways, while accidents are also linked to inadequate infrastructure, faulty railway components such as switches (Bădău, 2022), and broader management or human errors. Unintentional incidents, including passenger accidents and suicides, further complicate safety management. Additionally, vulnerabilities within train stations—such as noise pollution (Yildirim, 2021) and the ability to manage emergencies effectively (Han, 2020)—require continuous monitoring and improvement.

A core aspect of railway safety is **traffic control**. Modern approaches to risk analysis increasingly incorporate the *Reliability, Availability, Maintainability, and Safety (RAMS)* framework. Advanced technologies, including the Global Navigation Satellite System (GNSS) (Debiao, 2020) and high-speed communication systems like Long-Term Evolution for Railways (LTE-R) (Wen, 2020; Ahmad, 2020), are central to improving train localisation and real-time traffic management. The rapid growth of high-speed rail, combined with reduced headways, shorter departure intervals, and larger fleet sizes, has further intensified the complexity of safe train operations (Shangguan, 2022; Lin, 2021). Another significant challenge lies in **station scheduling and platform management**.

[1]*Assistant Professor, Department of Electrical Engineering, FET MJP Rohilkhand University Bareilly, India*
*atulkingpin@gmail.com*
[2]*Ph.D. Scholar, Department of Electrical Engineering, FET MJP Rohilkhand University Bareilly, India*
*akritistudy@gmail.com*
*(Corresponding Author)*
[3] *Ph.D. Scholar, Department of Electrical Engineering, FET MJP Rohilkhand University Bareilly, India*
*mukulpu@gmail.com*
*4 Assistant Professor, Deptt of Electrical Engineering FET, MJP Rohilkhand University, Bareilly, UP, India*
*ashish131@gmail.com*

Train operation scheduling and the coordination of multiple trains on the same platform are particularly critical in high-speed stations, where passenger numbers are increasing exponentially (Wijayanto, 2022). Optimised decomposition of train and station processes has been shown to enhance the occupancy balance of platform tracks, thereby improving system-wide safety (Xu, 2022).

However, human-related accidents—especially suicides involving trains—remain among the most severe issues for railway safety. Incidents such as deliberately lying on tracks or jumping in front of trains have devastating consequences (Woolery, 2021; Sahu, 2021; Preuss, 2020). Such events not only result in fatalities but also impose significant psychological impacts on train drivers, highlighting the need for structured support and intervention protocols (Bardon, 2021). The increasing demand for both passenger and freight rail transport further amplifies the stakes. Service interruptions caused by accidents generate major economic losses and inconvenience for users (Zhang, 2020). Moreover, studies reveal a significant disparity between *perceived safety* and *actual safety*. This perception gap directly influences passenger behaviour, both before and during travel. Measures such as visible security personnel and improved maintenance standards have been shown to positively affect passengers' sense of safety (Coppola, 2021).

Finally, railway platforms—especially the sections closest to tracks—represent critical safety hotspots. These areas expose passengers to risks during train arrivals, departures, or high-speed pass-throughs, making them a priority for safety innovation and preventive measures (Schneider, 2021). This paper therefore aims to provide a comprehensive assessment of the state of the art in railway safety, with particular emphasis on technological advancements and platform safety measures within stations.

## 2. METHODOLOGY

Relevant articles were identified and selected using the **Scopus database**. A **bibliometric analysis** was carried out to examine the significant contributions of authors, institutions, countries, and journals in the field. The study began with clearly defined **research objectives**. The **first stage of the review** included the selection of the database, formulation of keywords, and application of inclusion–exclusion criteria. This was followed by the **second stage**, which involved in-depth screening of the shortlisted studies. Finally, the **third stage** comprised the review itself, along with bibliometric and network analysis to evaluate research trends and interconnections.

## 3. REVIEW PROTOCOL

Accurate drafting of literature analysis is based on compliance with a rigorous standardised work protocol developed by a group of experts in 2005 and known by the acronym of PRISMA (Preferred Reporting Items for Systematic reviews and Me-ta-Analyses) Statement (Gurevitch, 2018). About a decade after the latest version, the PRISMA statement's major update was produced.

### 3.1 Databases, keywords, inclusion criteria

The information collection process in this study was conducted through a systematic literature review, enabling a comprehensive understanding of the state of the art related to the topic. The initial step involved defining a clear and effective strategy for the localization, selection, and inclusion of studies. Subsequently, research on railway safety was carried out using the Scopus database. Specific queries were formulated by entering targeted keywords into the search engine, including *"Safety," "Railway," "Station," "High-speed Train,"* and *"Suicide Railway."*

**Query 1**: "Safety", "Railway" and "Stations" in tiles-abstracts-keywords. This search returns 1406 documents. The publication window was restricted to the years 2020 through 2022. Additionally, only the English language was used in the studies. Finally, only scientific reviews and articles are considered (f.e. conference papers were excluded). The result is 151 documents as a result of these restrictions.

**Query 2**: "Suicide" and "Railway" in tiles- abstracts-keywords. This search returns 318 documents. The publication window was restricted to the years 2020 through 2022. Additionally, only the English language was used in the studies. Finally, only scientific reviews and articles are considered (f.e. conference papers were excluded). The result is 40 documents as a result of these restrictions.

- **Query 3**: "High-speed trains" and "Safety", and "Station" in titles-abstracts-keywords. This search returns 443 documents. The publication window was restricted to the years 2020 through 2022. Additionally, only the English language was used in

the studies. Finally, only scientific reviews and articles are considered (f.e. conference papers were excluded). The result is 57 documents as a result of these restrictions.

- **Query 4**: "Safety" and "Train" in titles-abstracts-keywords. This search returns 5710 documents. The publication window was restricted to the years 2020 through 2022. Additionally, only the English language was used in the studies. Finally, only scientific reviews and articles are taken into consideration (f.e. conference papers were excluded). The result is 137 documents as a result of these restrictions.

The result was to obtain 385 papers, reduced to a final database of 48 papers due to the exclusion of duplicates and eliminating all anonymous articles and all articles classified as "journal papers". A further selection was made by discarding all the articles that did not specifically concern the subject matter with a screening.

In order to help the writers convey their complete work, from the title to the conclusions, efficiently and transparently, Figure 1 outlines the screening, selection, and inclusion procedure for articles.

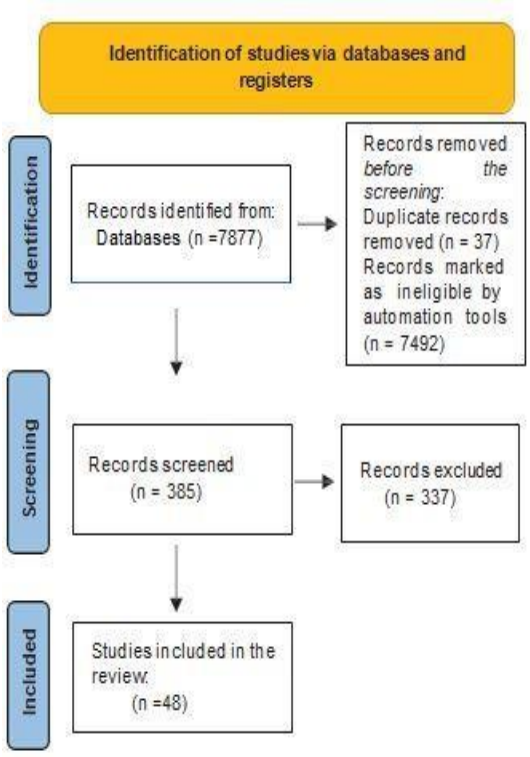


Fig 1. - PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

### 3.2 Classification

All 48 papers of the database, obtained previously, have been classified into two types:

**Article papers** (45), i.e., original research are reported in articles referred to as empirical or primary sources. An introduction, sections describing the procedures, and sections summarizing the findings will normally be present.

2. **Review papers** (3): i.e., papers synthesise or analyse research that has already been undertaken in primary sources and are sometimes referred to as literature reviews or secondary sources. They often provide an overview of the state of the research on a certain subject.

### 3.3 Keyword Analysis

This paragraph analyses all the various keywords obtained from the creation of the database. The results obtained correspond to those expected; the keywords most present, "Railway", "Railroad", "Railroad transportation" and "Safety", are those used to research various queries. A possible observation is that some keywords, such as "Suicide" and "Human" are also very frequent.

The reason is simple, and the "Railway" and "Safety" themes have the main link with human and accidental aspects.

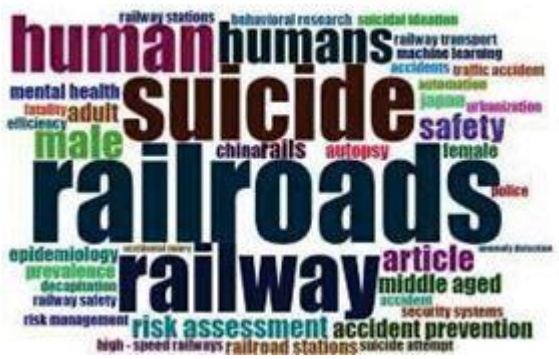


Fig. 2 - The world cloud of the top keywords used in the selected articles on the fields of railway safety

## 4. CURRENT SAFETY MANAGEMENT

In the years, many scientific studies focused on the research of methods to raise the speed and the

safety of trains. However, when a train derails, it can primarily result in financial losses in the form of crushed infrastructure or rolling stock, as well as more serious casualties and operational disruptions, all of which significantly negatively affect the railway industry's ability to develop sustainably.

Given the dynamic operational contexts, risk response is certainly highlighted as one of the most important aspects of the risk management process.

Since train and railways safety are complex, safety management is undoubtedly a critical issue to investigate.

Over 83% of all severe accidents on European railroads are due to obstructions on the track, and over 99% of all fatalities in rail transportation are attributable to such accidents. Each year, similar accidents on EU railroads result in the deaths of over 1,000 individuals (Rosić S., 2022).

Numerous research are analysing novel accident risk response techniques that can give railway safety managers and engineers a reliable and useful tool to select the optimum risk response strategy. (Zhang, 2020; Liu, 2020; Zhang, 2020; Catelani, 2021).

The high-speed railway system must get special attention since the safety of those facilities directly impacts the high-speed railway system's operational integrity: personnel, equipment, environment, and organisation management work together to control and achieve specific operation safety purposes.

Nowadays, automation is the new trend in railways development to increase its quality while maintaining a very high level of safety, mainly after electrification and the introduction of high-speed trains: is the base of the third revolution in the development of railway traffic. (Ramirez, 2022)

For this reason, artificial intelligence is a key tool for implementing safety automation instruments: autonomously operated trains, with the obstacle detection system, can increase the existing level of safety with the elimination of human errors and the recognition of obstacles in difficult conditions; and it can significantly increase transportation efficiency and decrease railway headway. (Chen, 2021).

Another recurrent problem is the lack of communication between trains. There is no direct information transfer between trains since each one uses the Global System for Mobile Communications-Railway (GSM-R) to interact with a Radio Blocking Center (RBC) and get Movement Authority (MA) to ensure its safe operation. (Wu, 2022). Many accidents occurred in the last years due to lack of communication, so experts are investigating new ways of communication-based artificial intelligence that can prevent railways disasters with the help of GPS and radar analysis. An example is the Centralised Traffic Control (CTC) system: an automated command system for remotely controlling railway operations that combines computer technology, network communication technology, and current control technology. (Zhang, 2022).

Machine Learning (ML) is now presented. ML is implemented to analyse accidents and enhance safety systems. Due to its capacity to draw relevant information from big data sets, it is a method for learning information through self-learning approaches that has been applied in every industry. For instance, the UK sector in charge of the trains has plans to digitise the sector.

Thus, the safety of stations and technology can be used to recognise any deficiency in those stations. A viable way to overcome uncertainty is machine learning (ML) methodology, which can learn from past data., as demonstrated in some simulations in the literature (Alawad, 2020). An application of ML is the implementation of an intelligent monitoring system for the platform security gate. This intelligent system adopts wireless communications to implement a self-automated organisation to manage the platform gates and improve safety (Li, 2022).

## 5. DISCUSSION SAFETY STATION

Cities all across the World have benefited greatly from investments in stations in terms of the economy and environment. To raise the overall standard of safety stations, Italy has specifically advocated a strategic programme for improving current infrastructure and renovating outdated stations across the national territory. (Coppola, 2022).

With the global high-speed network rail expansion, the high-speed railway passenger station is a very important hotspot for safety. The high-speed railway passenger station is an evolution of the standard railway passenger station: It is evolving into a brand-new class of urban transportation hub. Consequently, the high-speed railway passenger station adopts a significant amount of new technologies and apparatus, which introduces new characteristics to transportation organisation, passenger service, and

station management, such as multipart building structure, numerous internal apparatus, compact layout, wide traffic radiation, large passenger flow, and more concealed complex points.

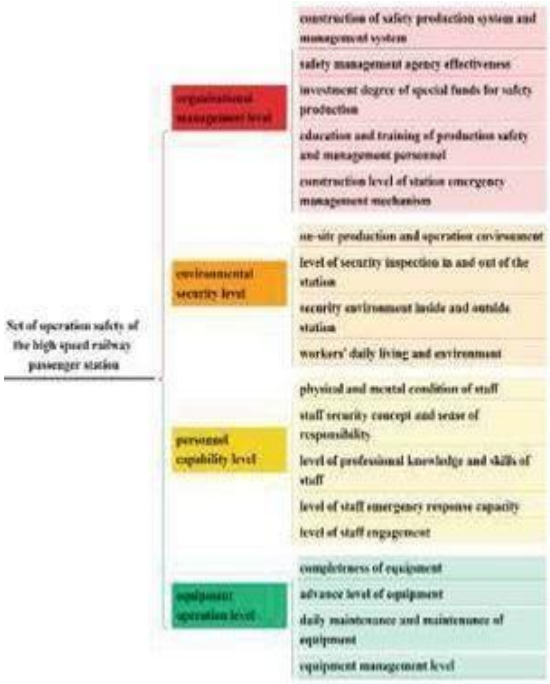


Fig. 3 - Set of operation safety of the high-speed railway passenger station

Moreover, it is important to highlight the travellers' choice of the main critical issues: an Italian study shows how road crossings are crucial aspects of railway safety. (Coppola, 2020)

An essential component of the transportation infrastructure is the level crossing. Here, the two types of traffic-regulated and unregulated-interact. Vehicles in the controlled rail traffic cross those in the unregulated road traffic. A rather small area is covered by this practise. However, the integrated processes are focused on long distances and medium speeds.

Additionally, it's important to consider the scene identification issue at level crossings, as seen from the train driver's perspective.

## 6. PLATFORM ACCIDENTS AND SUICIDE CASES- THE GLOBAL SITUATION

The platform is the most critical point in the complex system of the railway passenger station. The accidents that occur in the platform area have the worst consequences, both for people's life and the railway network. In particular, the aspect of suicides is the most relevant problem, and this paper aims to focus on this viewpoint. Many people tend to commit suicide on train tracks because they perceive instantaneous and certain death, plus it's seen as a good way to die. (Duddin, 2021).

A study in Japan illustrates the hotspots where accidents events take place: of 50 suicides, 48.0% occurred in front of benches or waiting rooms, 26.0% occurred at the front end of the platform, 24.0% occurred at the entrance to the platform, and 22.0% occurred at a blind spot for the train driver (Sueki, 2022). In Uk, indeed, every year, around 6000 suicides are recorded (Katsampa, 2022).

The first way to control and prevent these fatal accidents is modern Rail Network Surveillance; a case study on implementing an automatic sensor that can evaluate possible accidents has reported very good results (Zhang, 2022). Numerous studies today show how bystanders might be crucial in situations involving alleged suicide attempts on railroad networks. Such incidents can occur at times or places where only onlookers can respond by taking immediate action or sounding the alarm.

In Australia, a survey shows that over the period 2011- 2019, the number of deaths by rail suicide decreased by 73% (Ngo, 2021).

The train crossing level, as already said, represents a critical place for railway safety; a survey on the prevention of railway suicides in Australia through level crossing removal has shown a direct impact in decreasing the number of fatal accidents (Clapperton, 2022).

Nearly 3,000 suicides on trains occurred each year in Europe between 2012 and 2016, accounting for 73% of all fatalities on European railroads. (European Union Agency for Railways, 2018). Furthermore, as the population grows, the need for mobility is increasing and the strategies for reducing environmental impact (such as CO2 emissions) entail increasing rail transport volumes: for this reason, more railway suicides can be expected, and the attention on safety goals is very close. These arguments have led to the EU RESTRAIL project, which illustrates new tools for reducing suicides. Some examples of measures focused on suicide prevention are the installation of mid-platform fencing, gatekeeper training for front-line staff, anti-trespass grids, and the installation of forward-facing closed-circuit cameras on train CCTV.

A statistical survey in the Netherlands has revealed a discrepancy between expected and observed numbers of railway suicides since 2012 (Van Houwelingen, 2021). This divergence directly affects the implementation of safety features and encourages investments in railway safety systems in preventive measures.

In Denmark, a study illustrates critical places for suicides in stations, and the consecutive installation of signs, physical barriers, and motion-sensitive lights has brought in the next 14 months no suicides death cases (Erlangsen, 2021).

In Sweden, research concerns the restriction of access to suicide methods in the form of different physical barriers. In particular, the use of mid-track fencing between the high-speed and commuter train tracks was analysed. During the period of the study 2002-2021, the results on the line outside Stockholm demonstrated that suicides at highspeed tracks occurring at stations were the major cause of death on the investigated railway line. It is relevant that an easy to install and cheap mid-track fencing can largely decrease the number of suicides on a train line (Fredin-Knutzén, 2022).

Another proposal to improve station safety can be the installation of full-height platform screen doors, above all in stations with high-speed trains passing by.

In Finland, an important study has analysed all known measures for preventing railway suicides: some top safety measures adopted are the training of railway personnel, camera surveillance (a method already seen in other parts of the World), and detection systems like radar and movement sensors.

Future concrete work illustrating the use of novel safety methods in intelligent railway systems, where information regarding the techniques or epistemologies employed by safety experts can be considered for analysis, is anticipated. The researchers can also use the research proposals for additional analysis.

## 7. CONCLUSIONS

The increase in the use of public transport globally has increasingly raised concerns about the safety importance in railways. Therefore, there is an urgent need to implement new safety ways to help people and, in general, societies be more confident in the railway system, which manages sustainable and circular economies. This can be partially achieved by implementing new safety systems that can reduce the risk level in railways and avoid economic and life losses. A literature review of railway safety shows the actual methods adopted worldwide: the articles found in the literature show how the importance of safety is extremely high in China, the state with the longest high- speed Railway, and in Europe, which states are analysing many critical aspects of railway safety.

This study highlighted how the futuristic tools of artificial intelligence and machine learning could help the improvement of safety levels. For this reason, the collaboration between humans and robots is fundamental, and understanding how to improve this link is a key aspect of future research for railway safety. This article focused attention on safety in the platforms zone of stations. The platform, in fact, is a crucial hotspot for railway accidents that involve people: in particular, the study examined the case of train suicides. Suicides are very recurrent accidents on Railway. Many methods to reduce the number of these tragic events are analysed in this study, in particular, European Union invested in the project RESTRAIL, which principal aim is the prevention of suicides in the European Railway. Adopting new safety measures can aid in the collaboration of government leaders, service providers, and users to improve the transportation sector more broadly and develop safe, smart communities.

Additionally, a resilient model might be constructed to comprehend safety issues better, as indicated in the fatal incidents, which can be used to increase data collection on safety deficiencies and strengths for changes.

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