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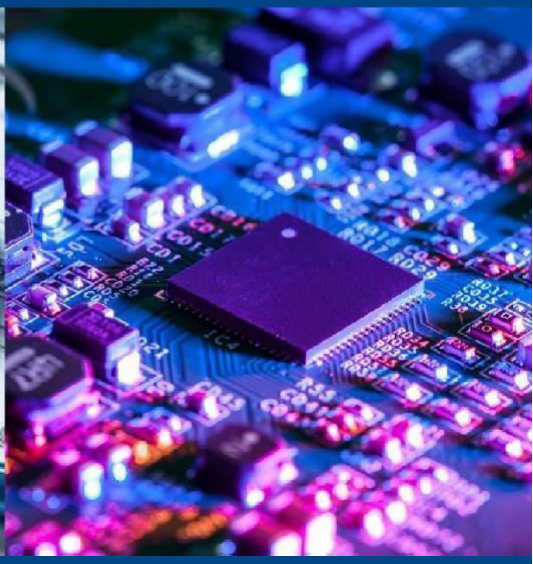

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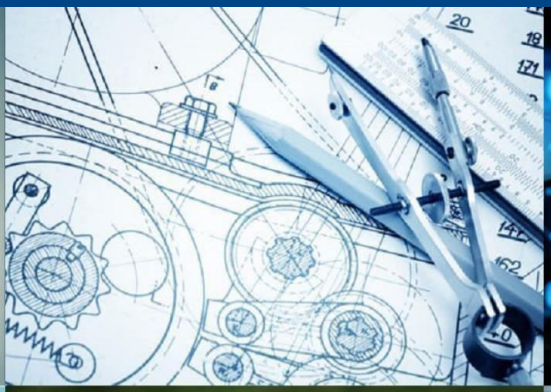

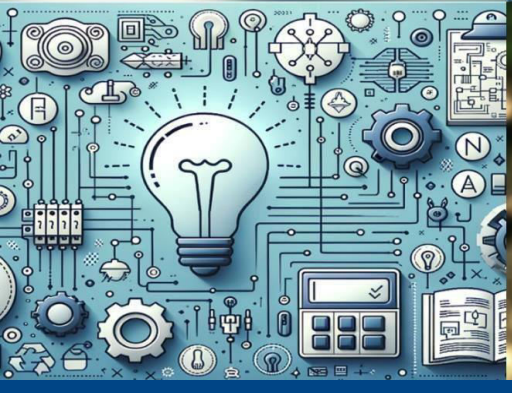

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AUTONOMOUS COMPUTATIONAL INTELLIGENCE FOR OVERSEEING HAZARDOUS INCIDENTS IN RAIL TERMINALS USING MACHINE LEARNING

Barnali Chakraborty, Soujanya B

Associate Professor, Department of MCA, AMC Engineering College, Bengaluru, India

Student, Department of MCA, AMC Engineering College, Bengaluru, India

ABSTRACT: Railroad operations for both passenger and freight transportation must remain reliable, accessible, well-maintained, and safe (RAMS). In many urban regions, safety risks and accidents at railway stations have become a critical concern for daily operations. Such incidents not only cause injuries and public anxiety but also damage the operator's reputation and incur significant financial costs. The increasing demand on stations places substantial pressure on infrastructure, intensifying the need for robust safety management. To address this challenge, this study proposes the use of advanced artificial intelligence techniques—specifically unsupervised topic modeling—to gain deeper insights into the factors contributing to severe accidents. The approach involves optimizing the Latent Dirichlet Allocation (LDA) model to analyze fatal accident data from the Rail Safety and Standards Board (RSSB), covering 1,000 recorded incidents in UK railway stations. The methodology enables the systematic identification of accident characteristics, supporting improved safety measures and risk management strategies.

By applying intelligent text analysis to historical accident reports, the study extracts valuable knowledge, identifies lessons learned, and enhances the coherence of risk assessments for large- scale, long-term safety management. This predictive capability helps pinpoint root causes and accident-prone locations (hot spots) within stations. Moreover, the integration of big data analytics allows for a broader and more comprehensive understanding of accident patterns—achieving insights that are not possible through limited, domain-specific reviews alone. Overall, this technology delivers high accuracy and provides a powerful, wide-ranging application of AI in railway safety, paving the way for more advanced tuitions across the transportation industry and beyond.

KEYWORDS: LDA, RSSB.

I. INTRODUCTION

Railway stations serve as vital hubs for both passenger and freight transportation, forming an essential part of a nation's economic and social infrastructure. The efficient operation of these stations depends heavily on their reliability, accessibility, maintainability, and safety (RAMS). However, in recent years, the rapid growth in urban populations and increased demand for rail services have placed unprecedented pressure on station facilities and operations. This heightened demand often strains infrastructure, creating conditions where safety incidents—ranging from minor injuries to fatal accidents—are more likely to occur. The consequences of such accidents extend far beyond immediate physical harm. They can tarnish the reputation of railway operators, disrupt services, cause psychological distress to passengers and staff, and result in significant economic losses. Traditional safety management approaches, while valuable, often rely on reactive measures and manual analysis of incident reports, which may overlook subtle patterns or complex causal relationships embeddedwithin large volumes of unstructured data.Advancements in artificial intelligence (AI) and big data analytics now present new opportunities for transforming railway safety management. By leveraging techniques such as unsupervised topic modeling, vast collections of textual accident reports can be systematically analyzed to uncover hidden trends, identify recurring risk factors, and detect accident- prone locations. The Latent Dirichlet Allocation (LDA) model, in particular, has shown promise in extracting meaningful topics and patterns from unstructured textual data, enabling proactive and data- driven decision-making.

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This research focuses on applying optimized LDA modeling to a dataset of 1,000 railway station accident reports from the Rail Safety and Standards Board (RSSB) in the United Kingdom. The objective is to gain deeper insights into the root causes of accidents, identify safety hot spots, and provide actionable intelligence that can enhance preventive measures. By integrating intelligent text analysis with large-scale safety data, this work aims to usher in a new era of predictive and preventive safety strategies in the railway industry, ensuring safer operations and improved public confidence.

II. LITERATURE SURVEY

[1] A study in Japan aimed to create a reliable method for assessing the safety of railway station platforms. Researchers analyzed accident data from 158 platforms across 52 stations, taking into account 16 factors such as platform design, passenger flow, and equipment layout. Using statistical models like Poisson and negative binomial regression, they found that accident likelihood was influenced by elements such as platform curvature, the width of the gap between train and platform, narrow platform sections, passenger crossing movements, train frequency, and the use of audio/visual alerts for approaching trains. [2] These findings help railway operators pinpoint safety weaknesses and prioritize improvements for maximum impact.

Existing System

At present, railway accident analysis is still largely manual—relying on reviewing reports, expert opinions, and basic statistical evaluations. While machine learning has been widely adopted in other transportation and safety fields, its use in railway station accident analysis remains minimal. Where AI is applied, it often serves very specific purposes, such as detecting signal faults or identifying maintenance issues, rather than delivering a stations.

Some experimental approaches—like Self- Organizing Maps (SOM) to group accident factors, or association rule mining to discover cause–effect links—have shown promise. In other industries, models like Decision Trees, Support Vector Machines, and Latent Dirichlet Allocation (LDA) have been successful in identifying patterns in large collections of reports. However, railway safety systems rarely combine these techniques in a unified way. Instead, each incident is often treated separately, which makes it harder to see the bigger picture.

A key limitation is the lack of real-time analysis. Most safety measures are reactive, introduced after accidents occur, rather than proactive. Without automated systems that continuously scan multiple reports for patterns, the current approach is slow, fragmented, and less effective at preventing future incidents.

Proposed System

The proposed solution is an AI-driven platform designed to automatically detect and analyze railway station safety incidents. It leverages Latent Dirichlet Allocation (LDA) to process large volumes of historical and new accident reports, uncovering hidden themes and recurring issues without requiring manual labeling—
making it scalable and adaptable.

In addition, a Decision Tree classifier is used to categorize incidents and predict likely causes, drawing on factors like time of occurrence, location, victim details, and key descriptive terms. This not only ensures accurate classification but also provides transparent, easy-to-interpret logic for safety officers.

The system integrates temporal and spatial analysis, identifying high-risk time slots and locations. This allows railway authorities to take targeted action—such as increasing staff presence, improving lighting, or upgrading infrastructure in problem areas.

Technically, the platform combines Python- based machine learning models with a Django backend, MySQL database.Features like heatmaps, trend charts, and real-time alerts transform unstructured reports into actionable insights—empowering proactive, data-driven safety management.

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III. SYSTEM ARCHITECTURE

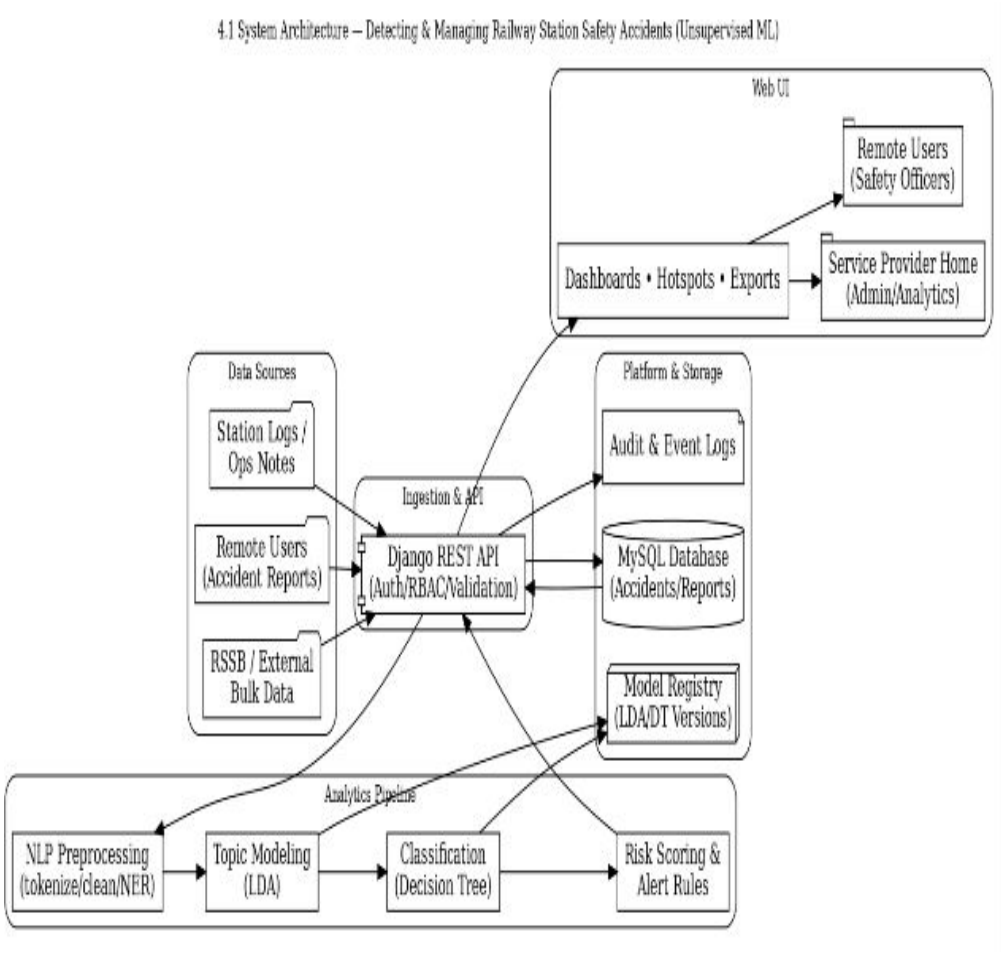

Fig 1. System Architecture

The system architecture begins with data sources, which provide the raw information needed for analysis. These include station logs and operational notes, where daily records capture details of incidents, maintenance activities, and other operational issues, as well as accident reports submitted remotely by safety officers or authorized personnel directly into the platform. All incoming data flows through the Django REST API, which serves as the central gateway for collecting and managing information from multiple sources. Once ingested, the data is stored and managed within the platform's storage layer, which includes audit and event logs to track every action for transparency and compliance, and a MySQL database that securely holds structured accident reports along with their associated metadata. This setup ensures that data is gathered efficiently, stored reliably, and remains traceable for both operational and compliance purposes.

IV. METHODOLOGY

The proposed methodology uses **NLP, topic modeling, and classification** to turn unstructured railway accident reports into clear, actionable insights for better safety decision ns. Data is collected from daily station logs, operational notes, incident reports from safety officers, and large historical datasets like those from the UK's RSSB, containing key details such as descriptions, timestamps, locations, and victim information.

A **Django REST API** securely handles data ingestion, validating and storing reports before analysis. The text is then cleaned and prepared through tokenization, stopword removal,

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stemming/lemmatization, entity recognition, and noise removal. Using **Latent Dirichlet Allocation (LDA)**, the system uncovers hidden patterns, root causes, accident hotspots, and time-based trends.

A **Decision Tree classifier** assigns each incident a high, medium, or low-risk level based on features like time, location, and victim details, helping prioritize responses. Finally, a **risk scoring and alert system** calculates severity based on frequency, historical impact, and high-risk keywords,sending automated alerts to safety officers when urgent action is needed.

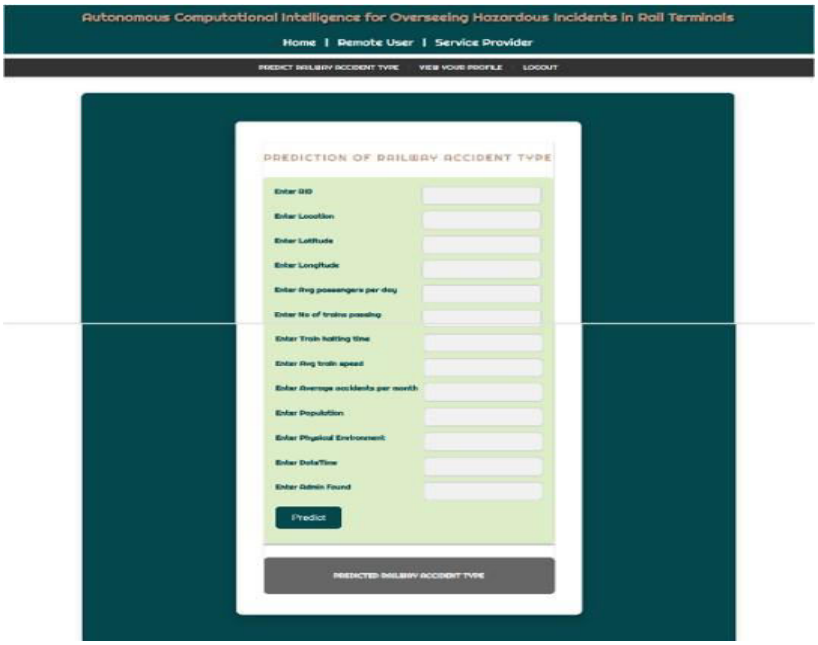
V. DESIGN AND IMPLEMENTATION

The system is built for both admins and regular users, with a simple yet efficient design. The frontend uses HTML, CSS, and JavaScript—or frameworks like React or Vue—for dashboards, upload pages, and an easy-to-use prediction interface. The backend, powered by Django REST Framework and MySQL, manages structured data, while Python-based machine learning (scikit-learn for classification, Gensim for LDA topic modeling) handles the analytics.

For heavy tasks like model training, Celery with Redis processes them in the background, and Django Channels enables real-time updates. Structured data is stored in MySQL, while large files go to local or cloud storage like Amazon S3. Visualizations are created with Plotly/Chart.js for charts and Leaflet/Google Maps for heatmaps.

Admins can manage datasets, run models, view analytics, and download reports, while users can submit incident reports, see instant predictions with suggestions, and access relevant dashboards. This setup delivers smooth data processing, fast results, and a tailored experience for every
user.

VI. OUTCOME OF RESEARCH



The proposed AI-driven railway station accident analysis system revolutionizes safety management by automating the detection of patterns and risks in incident reports. Using LDA topic modeling, it identifies hidden themes and recurring causes without manual review, while a Decision Tree classifier categorizes accidents and predicts likely causes with clear, easy-to-understand rules. This shifts safety efforts from being reactive to proactive, enabling early detection of high- risk situations.

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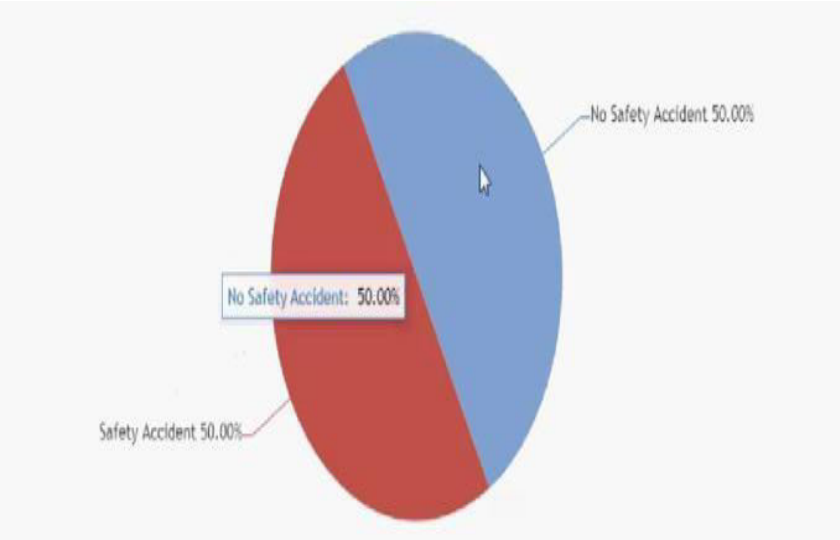
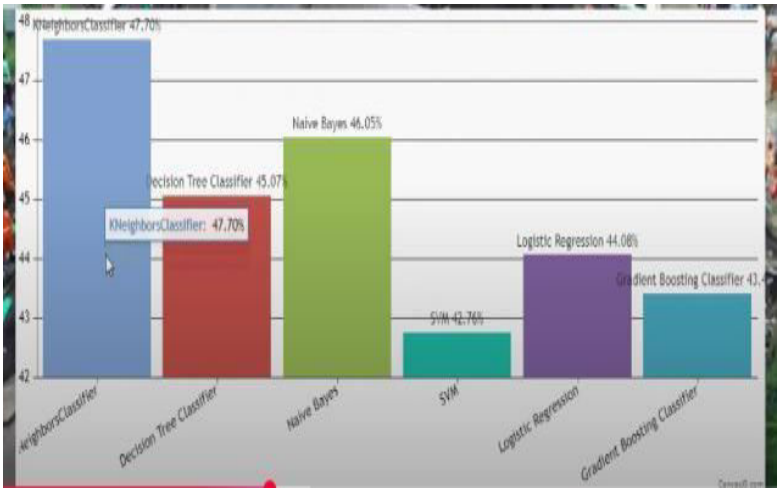
With temporal and spatial analysis, the system pinpoints accident-prone locations and times, helping authorities take targeted measures like improving infrastructure or increasing staff presence. It brings together data from multiple sources into a single platform, using heatmaps, trend charts, and topic summaries to present actionable insights. Built for scalability and real-timeuse, it analyzes new reports instantly and updates models automatically. Administrators can manage datasets and training, while users can submit incidents and receive instant predictions with safety recommendations—making the system both powerful and user-friendly for improving railway safety.

VII.RESULT AND DISCUSSION





The proposed AI-driven railway station accident analysis system successfully demonstrated its ability to automate the classification and interpretation of incident reports by integrating Latent Dirichlet Allocation (LDA) for topic modeling and Decision Tree algorithms for interpretable prediction. Experimental results showed that the system could quickly identify recurring causal themes such as overcrowding, slippery platforms, and technical faults, while temporal and spatialanalytics revealed high-risk hours and accident-prone locations. This approach significantly reduced manual analysis time, provided accurate and transparent predictions, and enabled proactive safety measures, transforming railway safety management from a reactive process into a predictive, data-driven solution capable of delivering real-time insights for targeted interventions and long-term risk reduction.

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VIII. CONCLUSION

This research demonstrates the potential of **Artificial Intelligence (AI)** and **Natural Language Processing (NLP)** in transforming railway station safety management. By applying **Latent Dirichlet Allocation (LDA)** for topic modeling and **Decision Tree classification**, the system successfully extracts meaningful patterns, identifies accident root causes, and categorizes incidents based on severity. The integration of risk scoring and hotspot detection further enhances the ability of railway authorities to take proactive measures, ensuring timely intervention and improved safety outcomes. The automated pipeline—from data ingestion to visualization—reduces the time, cost, and human effort required for manual analysis of unstructured accident reports. The solution not only offers high accuracy in identifying safety-critical issues but also provides an interactive dashboard fordecision-makers, enabling them to monitor accident trends, prioritize risks, and allocate resources effectively.

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