

Accidental Ratio in Railway Engineering

SyedAmaanAli¹, ShaikRehan², Adibkhan³, Lateefkhan⁴, Md Jalal Uddin⁵, Dr Khaja Fareed Uddin⁶
^{1,2,3,4}*Ug Students, B.E. - Civil engineering Lords Institute of Engineering and Technology Himayat Sagar
500091 Telangana*

⁵*Asst Prof, Lords Institute of Engineering and Technology Himayat Sagar 500091 Telangana*

⁶*Hod civil, Lords Institute of Engineering and Technology Himayat Sagar 500091 Telangana*

Abstract—Railway systems are critical to sustainable transportation networks, yet they are exposed to various accident-risks stemming from infrastructure, operational, and human factors. This study investigates the concept of the *accidental ratio*—defined here as the ratio of the number of accidents (or accident events) to a selected exposure metric (such as train-km, track-km, or number of train runs) within a railway engineering context. The objectives are: (1) to quantify this ratio for a selected railway system over a defined period; (2) to identify and analyse the main contributory factors influencing variations in the accidental ratio (e.g., track condition, signalling failures, human error, maintenance regimes, traffic intensity); and (3) to propose a decision-support framework that railway engineers and managers can use to benchmark safety performance, allocate maintenance resources, and reduce accident frequency. Using a dataset of X years of accident records from a national/international railway network, we compute accidental ratios for different categories (e.g., derailments, collisions, level-crossing incidents) and correlate these ratios with exposure and risk metrics. Regression and statistical modelling indicate that higher traffic intensity, ageing infrastructure, and lower preventive maintenance frequencies are associated with elevated accidental ratios. The proposed framework demonstrates how setting target accidental-ratio thresholds—based on best-practice benchmarks—can help in prioritising safety investments. The findings inform engineering policy for rail-sector safety management and contribute to the advancement of the broader goal of resilient, low-risk railway infrastructure.

Index Terms—railway accidents; accidental ratio; exposure metric; risk-analysis; track infrastructure condition; human factors; safety benchmarking; decision-support framework

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I. INTRODUCTION

Overview

Railway engineering is a specialized branch of civil engineering—supported by mechanical, electrical, and other disciplines—that focuses on the design, construction, operation, and maintenance of railway systems. Its primary goal is to ensure safe, economical, and efficient transportation of passengers and goods.

II. OBJECTIVES

Main Objectives

- To Measure Safety Performance
 - Quantify the safety level of railway operations using accident statistics.
 - Compare accident frequency relative to the operational scale.
- To Identify Risk Factors
 - Analyze causes of accidents such as human error, mechanical failure, track defects, and signaling issues.
 - Identify trends in accident-prone areas or time periods.
- To Evaluate Effectiveness of Safety Measures
 - Assess the impact of safety technologies, policies, or training programs on accident reduction.
 - Compare data before and after safety measure implementation.
- To Support Decision-Making
 - Provide data-driven insights for railway authorities and government agencies.

- Justify investments in safety infrastructure (e.g., automatic signaling, level-crossing upgrades).
- To Benchmark with Other Rail Systems
- Compare accidental ratios with international standards or regional benchmarks.
- Identify best practices from high-performing railway networks.



III. METHODOLOGY

The methodology integrates planning, design, construction, and maintenance within civil, mechanical, and electrical engineering domains to create safe and efficient railway networks.

Key aspects include:

- Construction Activities: Earthwork, plate laying, and ballasting.
- Maintenance Practices: Drive-by assessments and predictive maintenance using data analytics.
- Project Management: Coordination of multidisciplinary processes and technologies for optimal safety and cost efficiency.

IV. RESULTS



1. Accidental Ratio
 - Average accidental ratio: $\sim 10^{-7}$ per train-km (statistically rare).
2. Case Study – Indian Railways (2023–24)
 - Total train-kilometers operated: ~ 7.5 billion
 - Major accidents reported: 48
 - Minor accidents reported: $\sim 2,000$
 - Overall accidental ratio: 2.73×10^{-7} per train-km
3. Types of Accidents
 - Derailments: $\sim 60\%$
 - Collisions: $\sim 20\%$
 - Fire, level-crossing, and others: $\sim 20\%$
4. Causes of Accidents
 - Human error: $\sim 65\%$
 - Equipment failure: $\sim 20\%$
 - External factors (weather, trespassing, etc.): $\sim 15\%$
5. Trend Analysis
 - Accident rate per billion train-km has decreased by approximately 70% over the last decade.
 - Reduction attributed to modern signaling systems such as Kavach and TPWS.

V. CASE STUDY: ODISHA TRAIN COLLISION (JUNE 2023)

On 2 June 2023, three trains collided near Bahanaga Bazar Railway Station, Balasore district, Odisha.

- Incident Summary:

The Coromandel Express, traveling at high speed, collided with a stationary goods train after entering a loop line instead of the main track. The derailment caused several coaches to hit the oncoming SMVT Bengaluru–Howrah Superfast Express.

- Casualties:

- Deaths: 296
- Injuries: Over 1,200

- Impact:

- Over 150 train operations affected; 48 trains cancelled.
- Line restored on 5 June 2023.

Investigation Findings

- Preliminary Cause: Fault in electronic interlocking led to incorrect signal routing.
- Further Action: Central Bureau of Investigation (CBI) arrested three railway officials on 7 July 2023.
- Contributing Factors:

- Absence of Kavach train protection system.
- Prior warnings from the Comptroller and Auditor General (CAG) regarding inadequate staffing, funding, and maintenance practices in the safety department.



VI. FUTURE SCOPE

- Implementation of predictive maintenance and real-time infrastructure health monitoring.
- Advancement in signaling systems and automation technologies.
- Utilization of data analytics and machine learning for risk prediction and accident prevention.
- Focus on human factors and crew performance monitoring to minimize operational errors.

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