

Analysis of railway accidents in Nigeria: a decade of insights

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Article Info

Article history:

Received Dec 4, 2024

Revised May 25, 2025

Accepted Aug 28, 2025

Keywords:

Accident analysis
Fault tree analysis
Nigerian rail network
Railway accidents
Risk tree
Root cause analysis

ABSTRACT

This study provides insights into the patterns and dynamics of railway accidents in Nigeria over the past decade. Findings indicate that Nigeria's rail network experiences fewer but more severe accidents than the United States of America (USA) and United Kingdom (UK), with significantly higher fatalities and injuries per million train kilometers 92% and up to 95% more, respectively, in 2023. A top-down approach was employed to establish a risk tree, revealing six railway accident categories recorded over the last decade. The established risk tree could provide a framework for conducting the rail network's comprehensive safety risk assessment. Finally, a root cause analysis of railway intrusion accidents, the most occurring railway accident category in the Nigerian rail network, was conducted. Six immediate and eleven underlying causes (UC) of railway intrusion accidents were identified. About 62% of all intrusion accidents were caused by negligence of road users. Several actionable preventive measures (PM) have been proposed for each identified UC based on best practices in developed rail networks. Infrastructure upgrades and safety awareness campaigns have been identified as the potentially most effective PM for railway intrusion accidents in Nigeria.

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1. INTRODUCTION

Railway transportation has long been an essential component of Nigeria's economic and social fabric, dating back to the colonial era when the British colonial administration initiated the construction of railway lines to facilitate the extraction and exportation of natural resources [1], [2]. Over the last decade, Nigeria's railway network has undergone various phases of expansion and modernization, reflecting shifts in government priorities and technological advancements [3]. The Nigerian Railway Corporation (NRC), established in 1955, has been entrusted with managing and operating the country's railway system, overseeing a network of lines connecting major cities, ports, and industrial hubs [4].

Despite its historical significance and potential for economic growth, Nigeria's railway sector has faced persistent challenges, including inadequate funding, outdated infrastructure, operational inefficiencies,

and safety concerns [5]. The safety of railway operations has emerged as a pressing issue, particularly in light of the increasing frequency of safety incidents and accidents recorded across the network in recent years [6]. Against this backdrop, this paper embarks on a comprehensive analysis of railway accidents in Nigeria over the last decade. This timeframe encompasses a period of significant change and development within the Nigerian railway sector, marked by renewed government initiatives, infrastructure upgrades, and efforts to revitalize the country's rail network. Safety in railways refers to the measures and protocols implemented to protect passengers, employees, and infrastructure from accidents, incidents, and other hazards [7]. A railway system's safety could be measured using either a risk-level approach or an incident indicator [8].

The risk level approach, a qualitative approach, offers a defined classification of risks based on the frequency and severity of events [9]–[11]. These qualitative identifiers could be translated to numerical values to quantify the safety performance of a railway component, sub-system, or system [12]. On the other hand, the incident indicator approach is a purely quantitative assessment of safety that measures safety incidents over time [13]–[16]. Typical incident indicators set out by the European Union Agency for Railways (ERA) include the total number of serious accidents, distribution of accidents per accident category, and fatality risk indicator [17].

The significance of this research lies in its potential to provide valuable insights into the underlying factors contributing to railway accidents in Nigeria, offering a historical perspective on the evolution of safety challenges within the context of broader developments in the railway sector. This study aims to identify trends, patterns, and root causes by examining a decade's incident data, informing evidence-based strategies for enhancing railway safety standards and mitigating risks. The rest of the paper is structured as follows. The section describes the research data and methodology adopted in this study. Section 3 presents the results of the analysis and discusses the findings to derive insights. Section 4 provides conclusions on the results discussed, and section 5 ends the paper with some avenues for future research.

2. RESEARCH DATA AND METHOD

2.1. Data collection

Data on railway safety incidents in Nigeria were collected from two sources. A statistical summary of railway accidents was obtained from NRC's annual reports and official bulletins. Documented accounts of railway accidents were extracted from news reports to identify likely causal factors and establish a risk tree. The United States of America (USA) and United Kingdom (UK) were chosen for comparative analysis and benchmarking. Standard metrics used to compare the safety performance of rail networks based on incident indicators are annual railway injuries and fatalities per million train kilometers [18], [19]. Comparative data (annual train kilometers travelled, annual railway injuries, and fatalities recorded) were obtained from the Federal Railroad Administration (FRA) and Office of Rail and Road (ORR) databases for the USA and UK rail networks, respectively (Figure 1).

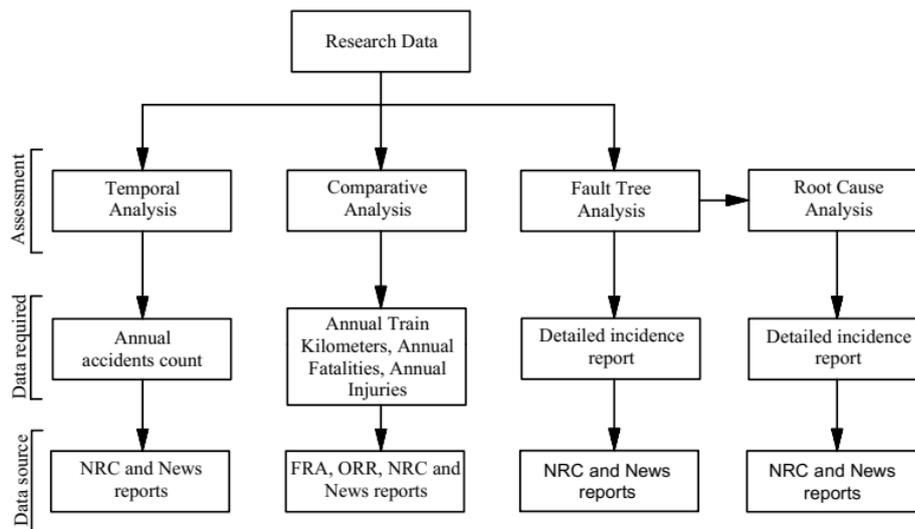


Figure 1. Research data and methodology

Data on train kilometres travelled within Nigeria's railway network is not readily available. As such, we devised a way of obtaining an estimate of the data. Train kilometres are obtained from both passenger and freight trains. When operational, passenger trains on the Nigerian railway network operate on a fixed timetable. Hence, train timetables for the train routes within the Nigerian rail network were obtained for passenger trains. The timetable provides information on number of weekly train trips along each route. Hence, annual train kilometres could be calculated by multiplying the number of trips each train makes in the year by the route distance. The periods in which train operations are suspended along a route are deducted from the annual total. Consideration was given to the period when new lines started operating to account for their actual contribution to the total annual train kilometres travelled.

The challenge lies in establishing the annual train kilometres travelled by freight trains since freight trains do not follow fixed timetables. Fortunately, the Nigerian Bureau of Statistics (NBS) publishes annual reports on revenue generated from rail freight transportation, with the routes responsible for such revenue. NRC annual reports also contain information that could allow for data wrangling to obtain estimates of annual freight train kilometres travelled.

2.2. Data analysis

Four types of assessments were conducted on the collected railway safety incident data. First, Nigerian railway safety incident data were subjected to descriptive statistical analysis to identify trends in the frequency, severity, and distribution of railway safety incidents over the study period. Next, the study conducts a comparative analysis of railway safety incidents in Nigeria with two advanced railway systems. Accident severity expressed in injuries and fatalities per million train kilometers travelled was used as a unit of comparison. The third assessment was conducted using a fault tree analysis to establish a top-down risk tree that depicts the causality chain of railway accidents in Nigeria. This risk tree serves as a basis for root-cause analysis of Nigeria's most dominant rail accident type (railway intrusion accident). Based on the root cause analysis, a comparative framework is used to assess the effectiveness of existing safety measures, identify gaps, and benchmark Nigeria's railway safety performance against global standards.

3. RESULTS AND DISCUSSION

3.1. Temporal distribution of railway accidents in Nigeria

Prior to 2022, the NRC and Nigeria Police Force (NPF) exclusively had the constitutional mandate to conduct investigations related to railway accidents. With the repeal of the Accident Investigation Bureau–Nigeria (AIB-N) Act 2006 and its replacement with the Nigerian Safety Investigation Bureau (NSIB) Act 2022, the mandate of conducting a comprehensive railway accident investigation now lies with the NSIB. So far, the NSIB has set out on its maiden railway accident investigation with the Public Works Department (PWD) level crossing (LC) accident in Lagos, which occurred on 9th March 2023.

Preliminary accident reports usually come from the NRC through press releases or the corporation's official website. However, in most cases, such reports fail to ascertain the severity of railway accidents, particularly the number of injured victims and the severity of such injuries. This is attributed to the fact that accident victims who sustain injuries seldom wait for response (or investigation) teams to arrive before discharging themselves, except in cases where the severity of injury is well pronounced. As such, when unavailable, such data was estimated using similar accidents with known severity and experts' inputs.

Figure 2 shows that the number of accidents and fatalities recorded in the first seven years of the last decade follows a similar trend, even after the increase in railway traffic with the introduction of the Abuja-Kaduna rail line in 2016. The terror attack on the Abuja-Kaduna train in 2022 saw the fatality count peaking at 9, even when only two railway accidents were recorded in the year. A similar trend could be observed with the annual injuries recorded (estimated) over the last decade. These results characterize the Nigerian railway system as semi-volatile, where little excitements result in severe consequences. Although there have been scenarios where accidents have been recorded with little or no casualties, the repeated occurrence of fewer annual accidents with severe severities calls for concern.

3.2. Comparative analysis

A direct comparison of the safety performance of diverse rail networks based on core safety metrics are not feasible due to differences in size, traffic volume, and safety investments peculiar to each network [20], [21]. However, by normalizing accident data with respect to the distance travelled by trains within each network, meaningful, and comparable insight into safety levels across diverse rail networks could be made. This study used injuries and fatalities per million train kilometers (pmtk) as normalizing indices. Lower values of injuries and fatalities pmtk indicate a safer railway system, highlighting effective safety measures and infrastructure maintenance [22]. Conversely, higher rates signal potential areas for improvement in safety protocols, infrastructure upgrades, or operational procedures.

Figures 3 and 4 present the safety performance of three countries based on the chosen indices. The choice of rail networks for comparison is guided primarily by data accessibility and the level of technological advancement of the rail networks. The USA and UK are considered to have some of the most advanced rail systems in the world [23]. This could be seen in how such networks operate with considerably low and relatively uniform fatalities and injuries pmtk (Figures 3 and 4). The same could not be said about Nigeria, where the fatalities pmtk varied haphazardly over the last decade. For example, in 2023, Nigeria recorded about 92% and 99% more fatalities pmtk than the USA and UK, respectively. In the same year, about 95% and 46% more injuries pmtk were recorded in Nigeria than in the USA and UK, respectively.

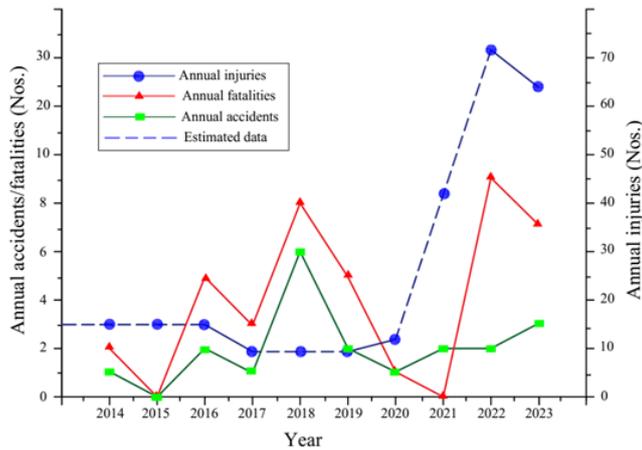


Figure 1. Temporal distribution of railway accidents in Nigeria

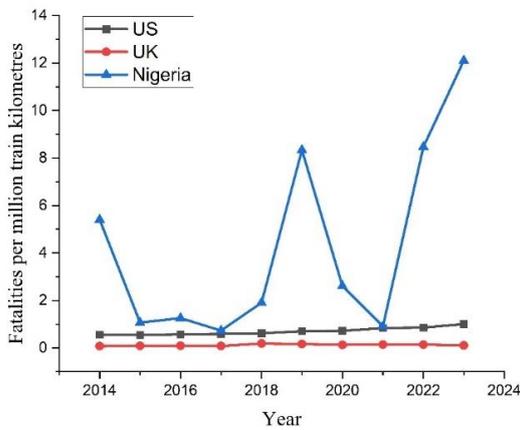


Figure 3. Comparative temporal distribution of railway fatalities pmtk

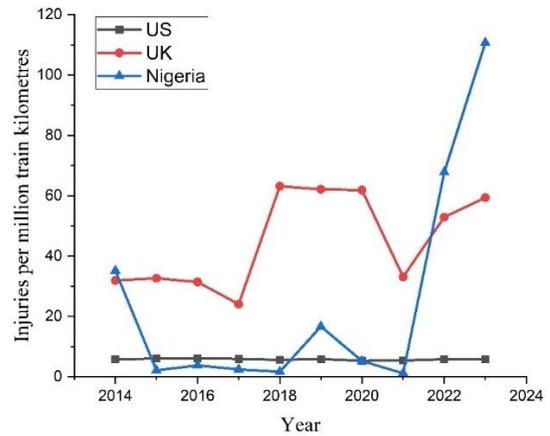


Figure 4. Comparative temporal distribution of railway injuries pmtk

However, Figure 4 shows more injuries pmtk recorded in the UK than in Nigeria over several years in the last decade. This is perhaps because more rail accidents in Nigeria resulted in fatalities than injuries. Another likely reason is the lack of an accurate record of the number of victims who sustained injuries in railway accidents. It is important to note that the FRA and ORR include all degrees of injuries when reporting the number of injuries in railway accidents. This is not always the case, as most victims with minor injuries in rail accidents in Nigeria often disappear before the arrival of any investigation or emergency team.

3.3. Fault tree analysis

In safety risk assessment, one of the critical stages in the process is developing a risk (fault) tree. Such a tree is usually developed from historical data of likely causes of the top event [24]. In this study, we used a top-down approach to develop a risk tree that defines the taxonomy of railway accidents in Nigeria.

Figure 5 shows the risk tree with four levels. At the top level is the main event (railway accident). This is followed by the first-level events that define the various categories of railway accidents recorded in the Nigerian rail network. At the second event level, the likely scenarios of consequences of each accident type are defined. The tree ends with base-level events, which are the various hazards that could lead to the occurrence of an accident type. It is worth noting that the assessment does not consider accidents that occur at railway station buildings, such as slips and falls.

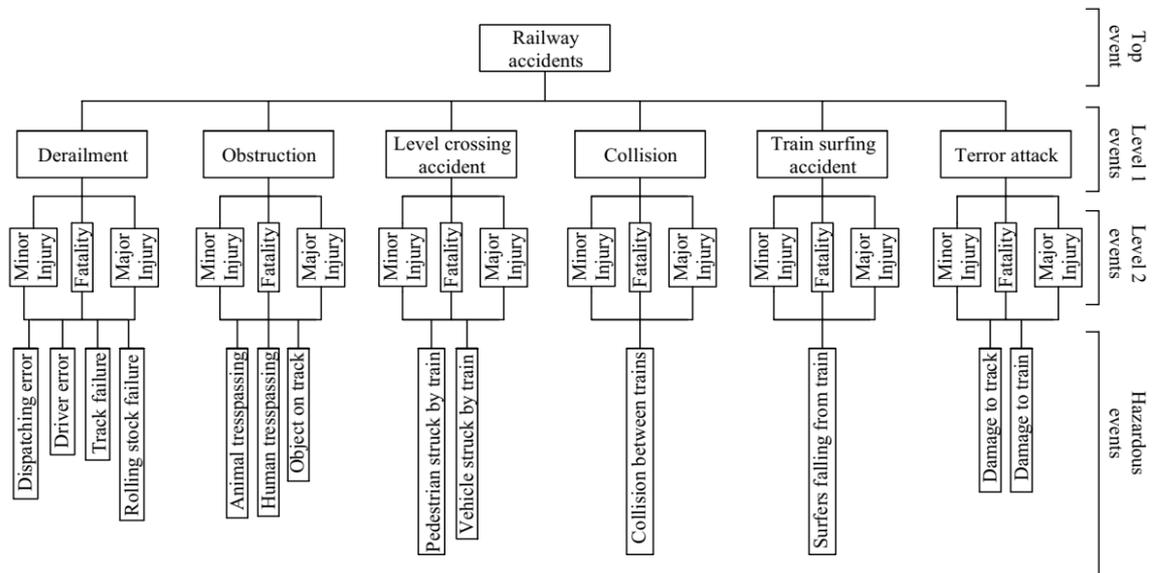


Figure 5. Risk tree of railway accidents in Nigeria

The risk tree presented in Figure 5 could serve as the building block for a comprehensive risk assessment, which typically progresses with assigning probability likelihoods and consequences of each hazardous event to determine the risk level of the rail network. However, this is not the scope of this study. In this study, we used the established risk tree to further investigate the most frequent and severe accident category in the Nigerian rail network: intrusion accidents. This is carried out using a root-cause analysis and is presented in sub-section 3.4.

3.4. Root cause analysis of railway intrusion accidents

The scope of intrusion accidents in this analysis encompasses all railway accidents where unauthorized access to rail tracks causes an accident. As such, we included all LC accidents in the analysis. Table 1 provides factual details of safety incidents used for the analysis. The information in Table 1 was used to establish sets of immediate causes (IC), underlying causes (UC), and preventive measures (PM) as shown in Table 2. Figure 6 presents the root cause mapping of events to causes and PM.

About 62% of all intrusion accidents were caused by negligence of road users. An UC is a lack of safety education for road users on the safe use of level crossings. This is evident from the events' facts outlined in Table 1, which show that most level-crossing accidents occurred because the road user believed they could beat the train to the other end of the level-crossing. As such, awareness campaigns on LC safety are needed, particularly in the communities near railway lines. The findings in [25] also support this assertion. The long slumber of railway operations over the past decade necessitates intensive efforts to re-educate road users on safety at highway-rail crossings.

Other significant UC of most intrusion accidents are inadequate design and poor maintenance culture. Critical locations along rail lines have been identified where inappropriate highway-rail interactions were established. Congested commercial hubs where a grade separation is the only safe alternative were designed with level crossings. Similarly, there are instances where densely populated neighborhoods have no LC to access highways. These gave rise to illegal crossings created by residents, a source of several intrusion accidents. Other causes resulting from poor design include the non-provision of pedestrian and animal crossings along strategic locations. Instances have been recorded where a large herd of cattle intruded into the rail track due to a lack of animal crossing along a known herder's route.

Table 1. Factual details of railway intrusion events

Event ID	Event facts
E1	i) BRT bus was hit by a train at level crossing, ii) warning signs (alarm and lights) have been removed due to ongoing construction, iii) railway flag officer stationed at the crossing instructed road users to stop for incoming train, and iv) bus driver ignored calls by flag officer and bus passengers to stop.
E2	i) a train struck a truck at a level crossing, ii) the truck driver ignored train’s horn sound and calls for caution, iii). there is a faulty mechanical gate at the crossing, iv) truck was laden with animal feed and moves slowly, and v) upon impact with the train, the truck changed course and crushed a tricycle parked beside the rail track.
E3	i) a private car driver attempted crossing track at an undesignated crossing, ii) the car got stuck on track due to elevation of the tracks, iii) the driver panicked and attempted exiting the vehicle, and iv) train struck and dragged the vehicle with the driver.
E4	i) a bus was struck by a train at a level crossing, ii) bus was dragged by train for hundreds of meters, iii) a vehicle parked close to the track was hit by the dragged bus and carried along by the train, and iv) the LC was manned by a railway flag officer.
E5	i) a train struck a bus while turning at a level crossing, ii) bus driver ignored warning from road users about the approaching train, iii) the only warning system in place is the approaching train’s horn, and iv) train surfers fell off the train upon impact.
E6	i) a train struck a tricycle with six occupants on board, ii) the tricycle driver refused to heed calls from nearby road users, and iii) there was no barrier at the crossing, and the only warning system was the train’s horn.
E7	i) a motorcyclist was struck by a train at a level crossing, ii) the only warning system at the crossing is a passive road sign, and iii) the motorcyclist refused to obey the train’s warning horn and calls for caution from other road users.
E8	i) a train derailed at a level crossing, ii) road users have reported Faulty tracks at the LC several times to the NRC, iii) the LC flag officer signaled the train driver to decelerate due to a faulty track, and iv) train driver refuses to follow instructions on reducing speed.
E9	i) a train struck a pedestrian while crossing the tracks at an undesignated crossing, ii) the victim was allegedly wearing a headphone while crossing the tracks, and iii) there was no designated pedestrian crossing in the vicinity.
E10	i) a train struck a pedestrian while crossing the track, ii) no fence is available to secure the right of way, and iii) no designated pedestrian crossing is available around the densely populated area.
E11	i) a man committed suicide by lying on train tracks in city suburbs, ii) a suicide note was found in the victim’s body after the incident, and iii) the incident occurred in city suburbs where no fence or barrier is provided to prevent unauthorized access to rail tracks.
E12	i) a herd of cattle was rammed into by a train exiting a curve, ii) the location is a known herder’s route, iii) the train driver sounded horn and applied emergency brakes, and iv) no designated animal crossing within the incident location.
E13	i) a train approached a LC and rammed into vehicles at the crossing, ii) there was no functioning active warning system at the crossing, iii) the train driver only sounded horn on approach once the train was too close to the level crossing, and iv) as a result, the train caught up with several vehicles at the level crossing.

Table 2. IC, UC, and identified PM

IC	UC	PM
IC1: road user negligence, IC2: commercial activities at level crossing, IC3: unauthorized access to track, IC4: train surfing, IC5: faulty tracks, and IC6: train driver recklessness.	UC1: inadequate safety training, UC2: poor safety culture, UC3: inadequate/poor design, UC4: inactive warning systems, UC5: unsecured right of way, UC6: lack of LC at a populated residential area, UC7: poor maintenance culture, UC8: lack of pedestrian crossing, UC9: lack of animal crossing, UC10: congestion at level crossing, and UC11: road vehicle overloading	PM1: provide LC safety education to road users, PM2: establish behavioral monitoring mechanisms for drivers, PM3: sanction reckless drivers, PM4: promote reporting unsafe conducts of drivers, PM5: provide LC at appropriate locations, PM6: replace LC with grade separation, PM7: provide adequate warning systems, PM8: secure rail right of way access, PM9: ensure proactive maintenance culture, PM10: provide pedestrian crossings at appropriate locations, PM11: provide animal crossings at appropriate locations, PM12: stop commercial activities at level crossings, and PM13: strictly enforce loading limits.

PM of railway intrusion accidents in Nigeria require infrastructure upgrades and massive awareness campaigns on railway safety, as shown in Figure 6. Figure 6(a) shows the safety events mapping to immediate and UC, while Figure 6(b) shows the safety events mapping to PM. Grabušić and Barić [26] identified infrastructure upgrade to be the key PM to railway intrusion accidents. Currently, the Lagos State Government, with support from the Federal Government of Nigeria, has initiated the process of replacing level crossings with grade separation at strategic locations in the state. This effort must be complemented by strict enforcement of safety laws that will ensure the eradication of illegal crossings and commercial activities near rail tracks. Similarly, several intrusion accidents could be avoided through safety awareness campaigns for road users and communities close to rail lines. Most road/road-rail intersection points in Nigeria are hawking and temporary commercial stalls hotspots. Usually, these activities are conducted right on the roadway/rail tracks. Most level crossings, especially those along the Cape gauge lines, have no active warning systems. At these level crossings, the only warning system to an approaching train is its blasting horn. As such, traders are often caught unawares.

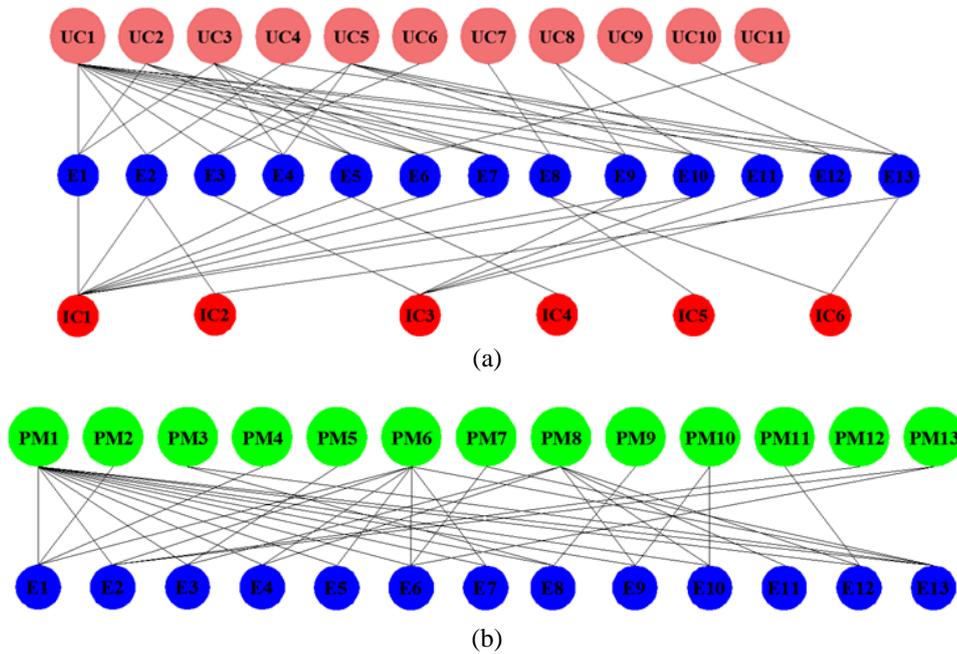


Figure 2. Root cause mapping of (a) safety events mapping to immediate and UC and (b) safety events mapping to PM

4. CONCLUSION

This study established the temporal distribution and comparative analysis of rail accidents in the Nigerian rail network over the last decade. A root cause analysis of the most occurring accident category was performed, and actionable PM were proposed. The temporal distribution of accidents suggests that the Nigerian rail network is semi-volatile, with few accidents resulting in severe consequences. The Nigerian rail network recorded considerably higher fatalities and injuries per million train kilometers than the USA and UK rail networks. The established risk tree revealed six railway accident categories recorded over the last decade. Six immediate and eleven UC of railway intrusion accidents were identified. About 62% of all intrusion accidents in the Nigerian rail network were caused by negligence of road users. Several actionable PM have been proposed for each identified UC based on best practices from developed rail networks. Infrastructure upgrades and safety awareness campaigns have been identified as the most effective PM for railway intrusion accidents in Nigeria.

5. FUTURE RESEARCH

Future research could explore the safety evaluation of the Nigerian rail network through quantitative risk assessment techniques. The risk tree developed in this study could serve as a starting point for risk quantification. Similarly, the various accident categories identified in this study could be further investigated to establish interrelationships between different safety events and provide holistic PM that could improve the overall safety outlook of the Nigerian rail network.

FUNDING INFORMATION

This research was funded by the Fundamental Research Grant Scheme (FRGS), grant number FRGS/1/2023/TK02/UTM/02/4, funded by the Ministry of Higher Education (MOHE), Malaysia. The first author acknowledges financial support from the Petroleum Technology Development Fund (PTDF), Nigeria, for his Ph.D. programme with award ID 22PHD074.

AUTHOR CONTRIBUTIONS STATEMENT

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C : Conceptualization

M : Methodology

So : Software

Va : Validation

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest between them regarding the publication of this article.

INFORMED CONSENT

This study does not involve human subjects or personal information requiring informed consent.

ETHICAL APPROVAL

This study does not involve human subjects or animal experiments.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

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