MOBILITY SOLUTIONS IN SOUTHERN AFRICA: CHALLENGES OF RAILWAY SAFETY AND SECURITY FOR HIGH-SPEED RAIL IMPLEMENTATION

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ABSTRACT

The High-Speed Rail (HSR) systems in Southern Africa play a crucial role in modern transportation, through boosting economic growth, reducing traffic congestion, improving logistics, and supporting environmental sustainability. However, the development of HSR in the region faces significant challenges relating to railway safety and security. This essay analyzes three major barriers, which includes the infrastructure vulnerability, derailments, and collisions, and their impact on rail modernization. By reviewing studies and data, the essay explores the socio-economic effects of these issues and then recommends technological solutions such as the Positive Train Control (PTC), IoT-based monitoring, and smart traffic management. The essay emphasizes the need for infrastructure upgrade, policy change, and collaboration among stakeholders to prepare the Southern Africa's rail sector for the future demands.

Keywords: High-Speed Rail (HSR), Railway safety and security, Infrastructure vulnerability. Rail derailments and collisions, Transportation innovation.

1. INTRODUCTION

South Africa's railway system, established in the late 19th century, was crucial for industrialization and economic growth, originally intended for mining and agricultural exports. It evolved into an essential national infrastructure, facilitating trade and urbanization (Staff Reporter, 2024; Transnet). At its peak, South Africa had one of the most extensive rail networks globally, managed by Transnet Freight Rail and PRASA. However, underinvestment and mismanagement now hinder progress toward HSR development. Research by Celestin (2023) and Su et al. (2024) shows that HSR can enhance mobility, reduce congestion, and cut logistics costs by up to 50% while promoting sustainability. Nonetheless, HSR implementation in Southern Africa encounters significant safety and security challenges (Railway Supply 2025). This essay explores derailments and infrastructure vulnerabilities. It also offers innovative solutions to improve mobility and contribute to discussions on optimizing transportation systems in Southern Africa.

1.1 Background of the Study

The rail density in Southern Africa is low, with just 3 kilometers per 1,000 square kilometers, compared to Europe's 400 kilometers (Vilardell & Espinosa Mateo, 2023). Historically, rail investments have focused on freight corridors in mineral-rich areas, neglecting passenger services and intercity connections. Infrastructure suffers from aging components, inadequate maintenance, and theft, which undermine reliability and safety. In contrast, HSR systems, in other parts of the world such as in central China, positively

impact economies by increasing revenue, job creation, and worker satisfaction. Guo and Ke (2020) report HSR-related industries account for 66.1% of economic activity and a 58.4% rise in wage payouts across large enterprises, SMEs, and technology sectors, as shown in Table 1 below.

Table 1: HSR Economic Benefits, effects of Cost Tolerance, Labor Demand, and Wages

Impact Categories	Large Enterprises	Small Businesses (SMEs)	Tech and Influential Sectors	Total
Expenditure	+22.3%	+15.1%	+28.7%	+66.1%
Job creation	+18.5%	+12.2%	+24.9%	+55.6%
Wage Compensation	+19.8%	+13.4%	+25.2%	+58.4%
Total	+60.6%	+40.7%	+78.8%	180.1%

Source: Guo, B & Ke, J (2020)

Despite the significant success of HSR in central China, the implementation of HSR in Southern Africa faces considerable challenges, particularly related to railway safety and security (Railway Supply, 2025).

1.2 Problem Statement

Railway safety and security present significant challenges to HSR implementation in Southern Africa. A Staff Reporter (2024) noted 687 collisions, 278 derailments, and over 7,420 security incidents in South Africa alone, leading to 74 fatalities and 98 injuries. The Railway Safety Regulator reported a 345.74% increase in security-related deaths from fiscal years 2022 to 2024. These statistics underscore the urgent need for structural improvements in infrastructure and operational protocols to enhance railway safety security.

1.3 Aim of the Essay

This essay examines the challenges imposed by railway safety and security issues towards the development of HSR in southern Africa, proposing innovative solutions to enhance rail transport safety and efficiency.

1.4 Scope of the Essay

The essay examines the challenges associated with the railway safety and security that hinder the development of HSR in Southern Africa. It addresses three key issues which include:

- Infrastructure Vulnerability: Its barriers toward limiting HSR development.
- Rail Derailments: Causes and their consequences.
- Rail Collisions: Its causes and preventions through innovation.

2. INFRASTRUCTURE VULNERABILITY

The fundamental framework of any High-Speed Rail (HSR) system is a robust and resilient infrastructure designed to accommodate elevated speeds and frequent operational schedules (Railway Supply, 2025). Nevertheless, a significant portion of Southern Africa's rail network was developed over a century ago and does not comply with contemporary design standards. As illustrated in Figure 1, numerous lines are afflicted by inadequate maintenance, infrastructure degradation, signaling malfunctions, and acts of vandalism, resulting in a substantial risk of service disruptions (Payne, 2022).

Source: Payne. (2022) (Image 1: Brenton Geach; 2: Leon Sadiki; 3: Shiraaz Mohamed)

Figure 1: Dilapidated rail infrastructure in Southern Africa

These deficiencies not only diminish operational efficiency but also elevate the risk of derailments and collisions within transportation networks. Without substantial investment in infrastructure renewal, including the modernization of rail tracks, bridges, tunnels, and the implementation of advanced digital signaling systems, the region will face challenges in accommodating the demands of high-speed rail transportation.

3. RAIL DERAILMENTS

Derailments pose a significant safety hazard in rail transport (Räty, 2024). Major contributing factors include rail infrastructure deterioration, defective wheel components, faulty switches, and human error. In Southern Africa, outdated signaling and poor maintenance exacerbate these issues. In 2024, there were 278 reported derailments, leading to casualties and economic losses (Staff Reporter, 2024; Gordon, 2024). Human factors, like workforce fatigue and inadequate training, also play a role. Authors such as Fisher and Chung (2025) highlight the need for the ongoing education and real-time monitoring to improve derailment prevention.

4. RAIL COLLISIONS

The rail collisions frequently occur due to the inadequate coordination, signal issues, or unauthorized access to the tracks. The risk of head-on and rear-end collisions increases in congested areas (Uflaz et al., 2023). According to the Japan Transport Safety Board (JTSB, 2024), even a small oversight error can lead to severe repercussions. Implementing advanced train control technologies such as Positive Train Control (PTC) is crucial to mitigate collisions. PTC tracks motions and automatically applies brakes when a possible collision is detected using GPS technology, wireless connection, and onboard devices (FRA, 2023; NTSB, 2023). Some of the vital preventative measures of accidents include separating freight and passenger rail lines, improving visibility at crossings, and enforcing access restrictions near tracks.

5. PROPOSED SOLUTIONS

5.1 Upgrading of Infrastructure

Developing a rail network necessitates a crucial financial investment and careful long-term planning. Key areas that require developing are outlined below which include:

- Upgrading the old tracks with welded rails to reduce vibrations and wear.
- Intensify the stability by the installation of ballast mats and concrete sleepers.
- Digitizing of signaling systems through advanced implementation of Global System for Mobile Communications – Railway (GSM-R) and European Rail Traffic Management System (ERTMS).
- Enhancing the standard and safety of bridge and tunnel structures to align with international safety standards.

5.2 Strategies for Isolation

In order to maximize the safety and security of the rail corridor and mitigate instances of unauthorized intrusion, it is proposed to implement the following isolation strategies:

- Physical barriers and fencing systems in high-risk areas sections.
- Utilizing motion sensors along with CCTV surveillance for identifying trespassers.
- Drone surveillance in high-risk regions and hard-to-reach locations.
- Programs designed to engage the community and promote awareness of rail safety.

5.3 Operational Management

Operational excellence is crucial for ensuring safety and efficiency in high-speed rail. Key proposals included in the table below:

Table 2: Operational control proposed solutions

Smart Detection Systems	Redundant Design	Automated Control Technologies
Utilizing embedded sensors, **Track Monitoring Systems** detect rail defects, temperature fluctuations, and load imbalances. **Wheel Condition Monitors** perform real-time diagnostics of wheel integrity through acoustic and vibration analysis. Additionally, **AI-Based Predictive Maintenance** employs machine learning algorithms to foresee component failures before they occur.	Configurations with dual tracks enable safe movement during maintenance or emergencies. Backup power and communication systems guarantee continuous operation. Fail-safe braking systems and redundant signaling are implemented paths.	**Positive Train Control (PTC):** Ensures compliance with speed regulations, avoids train collisions, and activates emergency stops when required. **Automatic Train Operation (ATO):** Facilitates fully automated or semi-autonomous train operations, enhancing precision and reliability. **Head-Up Displays (HUD):** Delivers real-time situational awareness to drivers without causing distractions from the track.

These technologies improve safety while also improving timely arrival, minimizing delays, and decreasing long-term operating expenses (UKTI 2019).

6. CONCLUSION

Implementing High-Speed Rail in Southern Africa presents numerous challenges, especially regarding safety and security. Nevertheless, by making strategic investments in infrastructure, isolation protocols, and smart operational controls, the region can reshape its rail system into a modern, efficient, and secure transportation model. By adopting innovations like PTC, IoT-enabled monitoring, and predictive maintenance, Southern Africa can break free from historical constraints and position itself as a regional leader in rail development. This advancement will not only rebuild public trust but also open up new economic prospects and foster sustainable development throughout the Southern African region.

7. REFERENCES

Celestin, M. 2023. 'The future of Hyperloop and high-speed rail in reshaping global supply chain networks', *Brainae Journal of Business, Sciences and Technology*, 7(2):977-988.

Fisher, D & Chung, D. 2025. “The eyes and ears of the railway”: How frontline workers uphold safety through their occupational expertise and embodied epistemic authority.

Guo, B & Ke, J. 2020. 'The impacts of high-speed rail on sustainable economic development: Evidence from the central part of China', *Sustainability*, 12(6):2410.

Japan Transport Safety Board (JTSB). 2024. Railway Accident Investigation Reports and Safety Measures.

National Transportation Safety Board (NTSB) 2023. Railroad Investigation Report RIR-23-12: Analysis of Safety Issues in Restricted Speed Operations, End-of-Track Collisions.

Payne, S. 2022. Transnet and Prasa fork out billions to combat theft and vandalism. Daily Maverick, 8 June.

Railway Supply. 2025. South African rail security problems persist amid operational challenges, Railway Supply, 2 January.

Räty, L. 2024 Tracking 8 Safety Risks in Railway Industry.

Staff Reporter 2024. WEEKEND BRIEF: Rail safety report reveals worrying operational shortfalls.

Su, M, Li, Z, Su, Y, Chang, M & Liu, Y. 2024. ‘The opening of high-speed rail and economic growth: The moderating role of government efficiency and innovation environment’, *Sustainability*, 16(2):543.

Transnet. nd. Railway Country: 150 Years of Rail in South Africa.

Uflaz, E, Akyuz, E, Arslan, O, Gardoni, P, Turan, O & Aydin, M. 2023. Analysing human error contribution to ship collision risk in congested waters under the evidential reasoning SPAR-H extended fault tree analysis. *Ocean Engineering*, 287(1):115758.

Vilardell, JM & Espinosa Mateo, M. 2023. Reform schemes for African railway and road.