

# *Abstract*

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The growing demand for faster transportation and increasing traffic are putting significant pressure on global railway and highway systems. Railways, a key element of the transportation network, efficiently and sustainably move passengers and goods using locomotives and rails. Compared to road transportation, railways are more environmentally friendly and cost-effective, reducing carbon emissions and fuel consumption. They play a crucial role in connecting cities, regions, and countries, promoting economic growth while alleviating road congestion and minimizing environmental impacts. Railway signaling systems, much like traffic lights for roads, are vital for managing train movements and ensuring safe and efficient operations. These systems provide train operators with instructions on when to stop, proceed, and control speed, thus preventing accidents and maintaining organized train traffic. With fast-moving and heavy trains, signaling systems are crucial to avoiding collisions, aided by track circuits and interlocking systems that help detect train positions and ensure safe distances between trains.

In complex rail networks, these systems control the flow of trains, manage track changes using switches, and handle emergencies like derailments by halting trains and rerouting traffic. High-speed trains, in particular, rely on advanced signaling due to their longer braking distances. These systems integrate mechanical, electrical, and electronic components, making safety dependent on their combined performance along with that of human operators. In India, the government-run Indian Railways operates with diverse signaling systems, often influenced by environmental factors. Research focuses on the Kolkata Metro, India's first metro system, operational since 1984. Covering a 27.22 km network and serving over 650,000 passengers daily, the metro is a critical part of Kolkata's public transportation. Metro Railways, known for being cost-effective and eco-friendly, helps reduce road congestion through its rapid transit systems. Among its subsystems, the axle counter plays a critical role in detecting train occupancy on tracks, and its failure can disrupt operations. This paper analyzes the failure patterns of axle counters and estimates their availability. Over 15 months, the overall equipment effectiveness (OEE) was approximately 75%, with a

10% variation. The study further examines the reliability, availability, and maintainability of axle counters in metro railway systems. Here, Failure analysis of railway signaling components one of the important issues in recent times, image processing has become an essential tool for quality control across various industries, especially for identifying deformities by comparing distorted images to reference images. This technique can be applied to assess the failure of metal-to-carbon relays, a crucial component in Indian railway signaling systems. These relays, made with silver-impregnated graphite (SIG) and silver contacts, function by making or breaking connections based on signaling logic. However, oxide and sulphide layers can form on the SIG contacts, increasing resistance and reducing reliability, which compromises rail safety and speed. This study utilizes image processing to analyze the failure of SIG contacts and assess their impact on relay performance. In recent times, image processing has become an essential tool for quality control across various industries, especially for identifying deformities by comparing distorted images to reference images. This technique can be applied to assess the failure of metal-to-carbon relays, a crucial component in Indian railway signaling systems. These relays, made with silver-impregnated graphite (SIG) and silver contacts, function by making or breaking connections based on signaling logic. However, oxide and sulphide layers can form on the SIG contacts, increasing resistance and reducing reliability, which compromises rail safety and speed. This study utilizes image processing to analyze the failure of SIG contacts and assess their impact on relay performance.