Evaluating the link between abnormal working and occurrence of collisions

APP STATE OF SAFETY INTERVENTION RESEARCH STUDY			
EVALUATING THE LINK BETWEEN ABNORMAL WORKING AND OCCURRENCE OF COLLISIONS REPORT			
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Executive Summary

Railway collisions during movement of rolling stock are ordinarily serious incidents that can result in fatalities, injuries, and significant financial costs. Since the railway industry is a form of a complex socio-technical system, an array of different systems will influence safe railway operations. As most aspects of technological systems involve the human element in terms of construction, design, management, operation, maintenance, and regulation, it is important that the impact of human factors on collisions is understood. According to data gathered by the Railway Safety Regulator, there are still many collisions reported each year, which is both noteworthy and alarming. Previous research conducted (A study on the Human Factor causality associated with mainline collisions) in collisions highlighted a need to evaluate the contribution of abnormal working on collisions to better understand factors that contribute to collisions within the South African railway industry.

The objective of this study was to identify the link between abnormal working and collisions on the mainline at Transnet Freight Rail and Passenger Rail Agency of South Africa. The aim of this paper was also to further verify if there is any correlation between abnormal working and train collisions. The results are based on an analysis conducted on existing investigation reports on collisions between rolling stock in the mainline. Each report was analysed according to the factors that led to its outcome, the principal unsafe act involved, and the latent organisational factors involved in the collision. The results are also based on interviews conducted and questionnaires distributed at Transnet Freight Rail and Passenger Rail Agency of South Africa.

It was found that the link between collisions and abnormal working in the railway space involved several human factors related failures and deficiencies. The types of failures noted in this research that contributed to collisions were related to faulty equipment, poor communication, lack of supervision and training deficiencies.

Purpose of Research

Collisions impinge on the safety of railway passengers and employees, resulting often in injuries and fatalities in some instances. It is imperative that a more comprehensive understanding of these instances is pursued. This research project will set out to identify the link between abnormal working and collisions on the mainline at Transnet Freight Rail (TFR) and Passenger Rail Agency of South Africa (PRASA). This paper will further verify if there is any correlation between abnormal working and train collisions. This study will then highlight the gaps that increase the safety risks associated with the abnormal working process and propose recommendations for both TFR and PRASA to implement and address those gaps.

The study will focus on the category A-a: Collision between rolling stock on a running line. The main objective of this study will be to evaluate if abnormal working can be associated to increases in the likelihood of collisions. It is assumed that the establishment of an association between collisions and abnormal working may lead to the identification of additional safety gaps that can be closed to minimise the likelihood of collisions occurring.

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List of Acronyms/Definitions/Abbreviations

ACCIMAP	:	Accident Model and Process
ATP	:	Automatic Train Protection
ATCO	:	Air Traffic Controller
BBS	:	Behaviour Based Safety
BOI	:	Board of Inquiry
CC	:	Chief Controller
CTA	:	Cognitive Task Analysis
CREAM	:	Cognitive Reliability Analysis and Error Analysis Method
CS90	:	Control System developed in 1990
CTC	:	Centralised Traffic Control
FMS	:	Fatigue Management System
GNSS	:	Global Navigation Satellite System
HFACS	:	Human Factor Analysis and Classification System
HRA	:	Human Reliability Analysis
MTA	:	Manual Train Authorisation
PC	:	Time to Prevent a Collision
PCM	:	Perpetual Cycle Model
PPE	:	Physical Protective Equipment
PRASA	:	Passenger Rail Agency of South Africa
PSF	:	Performance Shaping Factors
RAMS	:	Reliability Availability Maintainability and Safety
RARA	:	Railway Action Reliability Assessment
RCAS	:	Railway Collision Avoidance System
RSR	:	Railway Safety Regulator
SA	:	South Africa
SANS	:	South African National Standards
SMS	:	Safety Management System
SPAD	:	Signal Passed at Danger
STAMP-CAST	:	Causal Analysis using System Theory
STS	:	Socio Technical System
TCO	:	Train Control Officer
TCEWS	:	Train Collision Early Warning System
TLC	:	Train Location Controller
TFR	:	Transnet Freight Rail
UK	:	United Kingdom

Definitions

Degraded mode: This is a state of a signalling system, when one of the conditions that are proven by the signalling system (track vacancy, opposing signal at danger, points detection, etc.) are not met. During this state the signal can never be cleared to display a proceed aspect hence the driver is then authorised by the Train Control Officer to pass a signal at danger and to enter a block.

Abnormal working: It is a method of moving trains when the signalling system is faulty, and the signals cannot display a proceed aspect. The authority is then communicated to the driver by the Train Control Officer via a trunk radio or a landline phone.

Manual Train Authorisations: If the signalling system is faulty, the Train Control Officer gives a train driver authority to enter a block after he/she has satisfied himself/herself that the block is unoccupied. The authority is issued to the driver by means of a trunk radio or a landline phone.

Train Collision: The train collision occurs when more than one trains enter a block. Types of collisions are rear, side, and head-on collisions.

1. Introduction

The Railway Safety Regulator (RSR) oversees the safety of South Africa's vast and complex railway network. It is South Africa's Regulatory body interest in promoting safe railway operations through appropriate support, monitoring and enforcement, guided by an enabling regulatory framework. Collisions between rolling stock and objects have historically contributed more than 90% of the total collisions reported during the past three financial years as opposed to collisions between rolling stock on a running line, which have contributed less than 2% of the total collisions. Most collisions are reported by TFR and PRASA, with TFR reporting a higher number of collisions. Despite an overall 53% reduction in train km since 2010/11 reporting period, collisions occurrences per million train km increased by 63,3% in the 2020/21 reporting period; operational occurrences per million train km decreased marginally by 2%. Operators recorded a 17,8% per million train km increase in SANS Category [A-a] collisions between rolling stock on a running line occurrence during the 2020/21 reporting period.

As the data collected by the RSR has indicated, the number of collisions reported annually remains high; the high instances of collisions recorded is both significant and concerning. It is therefore pertinent to study and understand the factors that contribute to collisions within the South African railway industry. One of those factors that may contribute to collisions may be abnormal working.

2. Literature Review

2.1. Degraded modes and occurrences

The operators have developed a culture where they try to keep the operations running despite the system failures. They end up adapting to the degraded mode as if it was the primary mode of working. It will be interesting to understand why operators behave in this manner. Several accidents in rail and air traffic domain occurred during degraded mode. To protect or guard against occurrences in degraded mode, thorough risk assessments should be conducted.

Management often places emphasis to continue with operations even when safety is compromised. Seven people were killed in the Glenbrook collision which occurred in New South Wales, Australia. An inter-urban passenger train collided with the rear of an Indian Pacific long distance passenger train that had slowed after reaching a failed signal. In this accident the study found that the operator had a culture of on time running where employees are made to prioritise timetable deadlines and overlook the malfunctions in the system.

Risk increases during degraded mode due to lack of training or safety culture. This was observed in the Glenbrook accident where the driver was not trained on which extra precaution to take when working with a train without Automatic Train Protection (ATP). The driver of inter urban train lacked training in the safe working unit/rules where it states that extra caution should be taken after passing an automatic signal at danger. If such caution was taken it would have enabled the inter-urban train to stop before colliding with the rear units of the Indian Pacific train.

The Glenbrook rail accident demonstrated that the risk of accidents is increased if the procedures or training are inadequate or if there is a lack of an appropriate safety culture.

Problems of competency and inadequate staffing undermines the performance during degraded modes. In the Uberlingen mid-air collision it was reported that the Air Traffic Controller (ATCO) was alone as the second ATCO was on a break. The remaining

ATCO had to single-handedly perform the tasks normally associated with the Radar Planner and Radar executive as well as the role of a Chief Controller alone. A workstation that is designed to be operated by several operators was now manned by one operator and that demanded various tasks to be performed by one controller as she/he moved between the different positions and played a significant part in undermining situation awareness.

2.1.1. Risk Assessment

Degraded mode eroded the safety margins that are usually protected by normal operating procedures. The paper will investigate whether operators adequately assess all risks associated with degraded mode of operation.

Abnormal or increased loadings can be tolerated for short periods provided that the potential hazards have been identified and appropriate mitigations have been introduced. Changes in normal operations can be approved by regulatory authorities provided that the extent and likelihood of negative outcomes have been considered.

2.1.2. Humans and Systems

Investigations into accidents, found that errors arose from interaction breakdowns between the human and automated systems (Sarter, Woods & Billings, 1997).

There is a need for the Safety Management System to be integrated throughout the operational process to decrease the number of accidents. The cognitive challenge experienced through automation ranged from system situational awareness, mental modelling, perception of risk, mental workload, anxiety and fatigue, decision making and learning and unlearning capacities (Crawford & Kift, 2018).

Behaviour Based Safety (BBS) is a technique that supports the development of an ideal safety culture. “The method aims to create an active safety partnership between workers and management.” (Crawford & Kift, 2018) It ensures that each individual attends to their own safety, focusing on what an individual does and safety interventions that they apply." Researchers are finding a positive link between BBS interventions and a reduction in accidents "(Crawford & Kift, 2018).

Design, installation, and maintenance tasks are influenced by human factor. Human Reliability Analysis (HRA) is used to estimate the human error. Railway systems are impacted by human reliability. There are innovative HRA methods customised for the railway systems. HRA is part of risk assessment. It is defined as the systematic study used to identify, quantify, and reduce the probability of a human error when the operator performs a specific task under certain conditions (Ciani et al., 2022) and it is a multi-disciplinary study. Human reliability analysis requires knowledge of psychology, medicine, and engineering. An operation performed by a human should always be considered part of the system and thus it is subject to error and fault (Ciani et al., 2022). Technique for human error rate prediction is a milestone of HRA procedures (Ciani et al., 2022).Second generation HRAs focus on the cognitive aspect of the operator as opposed to the first generation HRA that treated the operator as a component. The most famous second-generation method is called Cognitive Reliability and Error Analysis (CREAM) is based on four cognitive functions namely perception, interpretation, planning and action. There is lack of literature with regards to the HRA technique applied in the railway environment.

According to the International Union of Railways (UIC) annual safety report, human factor error is one of the main causes of railway accidents every year (Ciani et al., 2022).Human factor error contributes 5% of the total incidents which make it the second highest contributor to incidents.

Railway Action Reliability Assessment (RARA) is the only HRA technique developed for the railways. The UK is the country that has produced more journals on HRA in Europe. University of Nottingham in the United Kingdom and Network Rail are the institutions that have produced more research work on HRA. Mental workload of the Train Control Officers (TCOs) and train drivers need to be conducted to determine the mental workload threshold. The effect of pressure coming from punctuality for the drivers and analysis of the sleep patterns of the drivers need to be analysed.

In a broad range of situations in complex sociotechnical systems, from routine to abnormal conditions, to significant shocks or emergencies, human performance, actions, and decisions play a crucial role. While humans have been successful in coping with a (unexpected) situation, the times they have been unsuccessful have highlighted the operational and organisational shortcomings of the facility's preparedness.

Performance Shaping Factors (PSFs) include a sizeable range of possible factors from procedural guidance, human-machine interface ergonomics, to experience, training, and organisational safety culture.

The role of humans in completing the human-automation-technical loop to achieve safe and reliable operations is one of the most fundamental challenges in complex sociotechnical systems.

Humans in those systems are involved in an array of roles, from the physical, and psychological, to the political and ecological.

The analysis of rules, skills, and knowledge-based categories that are driven by local contingencies as well as long-range correlations are necessary to understand human performance in sociotechnical systems. Therefore, while small local actions alone may seem acceptable and safe, when combined with additional factors, those actions may tip the system in an unsafe direction. Rather than blaming people for errors, it's important to understand how these people acted in the given situation and try to make sense of their activities (Kyriakidis et al., 2018). Local and global determinants must be factored in when characterising human activity. That is, the long-term processes (comprising of slow system shifts towards danger) and short-term processes (immediate threats and failures) must equally be accounted for when characterising human performance in sociotechnical systems. The role of humans in complex sociotechnical systems and their related normative behaviours provide the basis of the systems' uninterrupted operation. Even when taken as normative, the actual activities, which are derived from the situational context, arise from ongoing contingencies and may not be entirely pre-planned and predictable. This could result in modifications in human behaviour and slip-ups and errors that could cause accidents.

Large sociotechnical systems are interaction-dominated and complex. They have numerous interconnected parts that interact on a variety of spatial and temporal domains, and the interactions among the parts take precedence. As a result, the idea of linear cause is overshadowed and replaced by a constraint-based view. As a result, human performance and behaviour can be understood as influenced by environmental limits.

The understanding of human performance in complex sociotechnical systems necessitates that we consider not only human behaviour (various factors such as the personality, motivation, will, among others) but also the understanding (and interpretation) of the surrounding technological context (providing opportunities and constraints for performance). This reciprocity and mutual shaping of the person and the adjoining technological environment is of critical concern when considering human performance in complex sociotechnical systems.

The interaction between humans and their operational environment as well as the effects of one on the other, is currently addressed through defining the factors that affect human performance in different operational contexts. These factors, approximately referred to as Performance Shaping Factors (PSFs), can be defined as ‘‘all these factors such as age, working conditions, team collaboration, mental and physical health, work experience or training which enhance or degrade human performance” (Boring et al., 2007, cited in Kyriakidis, 2018). It can thus be proposed that PSFs express all various, organisational, systemic, personal, situational, and environmental factors that may influence, positively or negatively, the performance of an individual.

The study on the evolution of variability in human task performance has shortcomings when it comes to exploring the interdependencies between physical and cognitive elements of human response.

Human task performance is influenced by both physical and cognitive abilities of the individual. Cognitive abilities refer to the ability to process information and make decisions based on environmental perceptions (see Figure 1), knowledge, and memory (Ciani et al., 2022). Physical abilities describe the coordinated muscle action needed to complete sustained effortful muscular action needed to complete sustained effortful muscular work (Ciani et al., 2022).The task environment (see Figure 1) comprise internal and external elements to the individual performing a task. The performance environment affects both physical and cognitive performance.

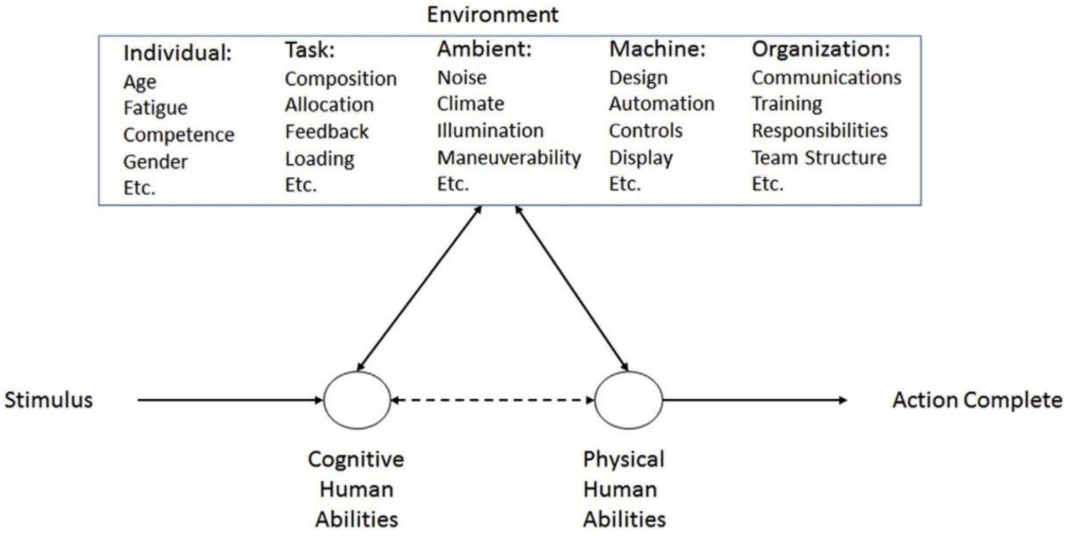

Figure 1:Physical and Cognitive Interdependencies within the STS environment (adapted from: Marras and Hancock,2014)

Figure 2: Causes of fatigue in the workplace (Adapted from: Sadeghnijat-Haghighi, 2015)

Reason (1997) states that most unsafe acts—possibly 90% or more—were without blame. There exists an agreed upon opinion that humans make errors because they are put into unfavourable conditions. According to this perspective, human error is a consequence rather than a cause (Liu et al., n.d.).

Regardless of how diligent and careful we are, human errors can still happen. However, as accident records show, human errors can be avoided. There are always administrative or technological measures that can be taken to avoid accidents caused by human error. By studying incidents, it has been demonstrated that many new product designs can be made intrinsically safer.

A system involving humans would bring up safety issues as they make mistakes, and currently, it is virtually impossible to totally remove humans from a system.

Since humans tend to make mistakes, a system involving them often raises safety concerns, and it is currently difficult to completely exclude humans from a system; even automatic or automated systems require humans to inspect their status periodically to avoid unpredicted failures.

Any time a human is involved, there is the potential for human error, which could result in a system failure. Such opportunities are always present for complex systems. As a result, a complex system's safety greatly depends on human performance.

Sanders and McCormick (Liu et al., 1993) define human error as “an inappropriate or undesirable human decision or behaviour that reduces, or has the potential for reducing effectiveness, safety, or system performance.” In accordance with this definition, a choice or action that might have unfavourable effects is nonetheless regarded as a human error even if those effects have not yet materialised.

Specific human errors may be predictable for some given situations. Moray & Senders (1991, cited in Liu, Zhang, Yin, & Li, 2021) found that human errors could be predicted based on the extent of mismatch between an operator’s capabilities to implement a task and the task demands. A detailed task analysis is first crucial to recognise mismatches between task demands and operator capabilities.

The research suggests that humans make errors because they are put in unfavourable conditions; the central strategy for human error control will therefore be to control the factors that create unfavourable conditions, and then heighten the humans’ capacity to work in unfavourable conditions (Via PPE, organisational interventions, etc.).

Human performance is influenced by the environment, the task, the individual, the tool/interface, work process and job object.

The following are the six prevailing trends that raise concern for safety in the railways:

- shifting cognitive challenges for operators of centralised control systems,

- end-user adoption of systems that continuously rise in complexity,
- the growing prevalence of sedentary work particularly in control rooms,
- developing data security and privacy concerns,
- expanding demands for data analytics and
- an emerging paradigm shift in safety practice

History has shown that safety practice developed as reactive responses to accidents. This approach to safety has been described as a ‘painful process of trial and error’ (Aldrich, 1997, p. 13).

2.2. Changes in stress and subjective workload over time following workload transition.

Workload transitions are instances where protracted stretches of high or low task demands are followed by a swift or gradual change in demand level. Workload transitions are concerned with how factors like performance, mental demand, and stress are affected by changes in workload over time (Messick Huey & Wickens, 1993).

An individual experiences stress when their perceived coping methods are deemed insufficient to lessen the stimulus that they consider to be upsetting. Compared to chronic stress, acute stress may have an appraised stimulus that is the current task.

Stress and performance may not always correlate monotonically, as physiological adaptations might enable a human operator to retain a particular level of task performance despite an increase in stress. Instead, greater stress is more likely to cause a rise in performance variability. At some point, the adaptive function will stop working, which will cause a dramatic collapse in task performance.

When determining whether to put more effort into an activity, performance improvement and energy conservation must be traded off. A reduction in goals is preferred to increased effort in response to changes in task demand if energy conservation takes precedence over task performance. Thus, there may be a goal regulation, an effort regulation (increase or reduction), or a mix of the two following a workload transition.

2.3. Analysis of rail signals passed at danger.

Human error is not a matter of personal control but an emergent property of the overall system design. The implementation of system thinking reflects on information captured (Kyriakidis et al., 2019).

The analysis of the theory of Social-Technical Systems (STS) highlights the following:

- Recognises the complexity of the interaction of people and technology in workplaces.

- The application of system thinking focusses on the interrelation and working constituent part overtime and appreciation that changing one part will affect the other parts and the whole system.
- It is important that blame is not implicated to the human error however utilizing the “just culture” to look at the whole system and fixing where there are problems that lead to human error such as workload analysis.
- The lack of identification of system level influencers that require change to reduce the potential of human errors. It is important that systems installed reduced the possibility of a human error from occurring.
- The investigations conclude that the outcome report is dependent on the person who conducted the investigation such as experience, having worked in the environment and how many times they have conducted investigation.
- The outcome of the investigations varied, and the actual root cause were not clear in some investigation report.
- A proposal was given to standardize the investigation reports after the analysis of various reports.

2.4. Train Collision Analysis

Few studies exist regarding how to evaluate the collision risk and provide an early warning concerning a preceding train on the railway. The timing of many events, including wireless connection delay, driver reaction, safety protection distance, and deceleration rate, the authors discovered, limits the amount of time available for accident avoidance. The time to avoid a collision is precisely determined when these timing factors are considered. The collision risk is established based on the time to prevent a collision to assess the potential crash severity when the subsequent train approaches.

The Train Collision Early Warning System (TCEWS) is used to highlight potential collision situations for drivers and is intended to deliver collision warning signals (Li et al., 2018). It is utilized as a safety guarantee by monitoring and tracking a train's motion condition. It functions fundamentally as a high-speed rail early warning system for train collisions.

Only the dispatcher has a general understanding of the traffic condition and must alert the train driver in the event of a potential collision, making TCEWS an independent technical supplemental approach. The TCEWS is made to be able to work as an active protection, giving drivers and management information about the train ahead of them and advising them to confirm the situation and reduce speed to avoid a collision.
The TCEWS should be one part of Automatic Train Protection (ATP) system and is independent from the existing signalling system.

Both the Railway Collision Avoidance System (RCAS) and the railroad Collision Avoidance System (CAS) evaluate the collision risk by the estimated braking distances. By dividing the Time to Avoid a Collision (TAC) into timing variables such wireless communication delay, driver response, safety protection distance, and train braking, we can analyse the TAC. The determination of the time necessary to prevent a collision is made using these timing elements. Then, based on the TAC, It is suggested that a collision risk is conducted to assess the conflict's seriousness and four-tier color-coded early warning system to instruct drivers on how to react to a collision threat is created.

The real-time contextual data gathered is used in the TCEWS to inform a collision avoidance strategy. The Train Location Controller (TLC) for instance, must determine the duration to a potential accident in a particular scenario and compare that to timed events like driver reaction time, wireless communication, Global Navigation Satellite System (GNSS)-based train positioning performance, and train braking. Additionally, based on the time of the events and the severity of the hazards, several alarms should be sent.

These timing events are dynamic and can vary depending on the environment, drivers, and train motion status. We must examine the important variables that affect the interval between the time a warning is delivered and the time a collision can be averted to develop the behaviour of a collision-avoidance method in TLC based on wireless communication and the dynamic timing events. This timing area is known as a collision timing avoidance zone.

2.5. Occurrence Investigation Methods

Ergonomics and Safety researchers have turned their attention towards applying combinations of **Sociotechnical methods** rather than using **single methods in isolation** (Hamim et al., 2022). For this research three methods were used to analyse level crossing incidents in Bangladesh:

1. Accident Model and Process (Accimap)-Theoretic method.
2. Causal Analysis using Systems Theory (Stamp-Cast) and
3. Perpetual Cycle Model (PCM)- cognitive approach.

Methods were separately used to investigate the collision (mixed method approach). The methods used led to a group of contributing factors and an array of safety recommendations. Unintentional non-compliance with rail level crossing by road users causes safety issues around the world (Hamim et al., 2022). According to International Union of Railways, 14.7% of the European Railway Incidents reported in 2018 came from Rail Level Crossings. In Bangladesh,235 rail level crossings occurrences were recorded in 2018, and these resulted in 244 fatalities and 228 injuries. Despite all these incidents in Bangladesh, 80% of their total level crossings remains unprotected.

It has been argued that the interactions among the many different actors of a system can be better understood using sociotechnical systems thinking approach (Hamim et al., 2022).The application of systems thinking can lead to **improved level crossings designs**. Most of the research on systems thinking approach has been conducted by the high-income countries, however the learnings from these studies can also benefit the low- and middle-income countries. Alongside advances in systems thinking and road safety, psychology and cognitive ergonomics field continues to be useful in helping us understand why collisions occur (Hamim et al., 2022).

The Perceptual Cycle Model (PCM) is useful in explaining the mechanisms underlying failures in human performance (Hamim et al., 2022). Systems methods are understood to represent a macro approach to collision analysis and cognitive ergonomics represent a micro approach. These approaches can be simultaneously used in collision investigations. The research assesses the combined application of two systems methods. The two systems are Accimap and Causal Analysis Based on the Systems Theoretic Accident Model and Process (STAMP CAST) with the Cognitive PCM approach used to investigate a **level crossing collision** in low-income countries.

The Accimap method is based on systems theory. Using this method, the contributing factors are mapped out on a hierarchical diagram. STAMP CAST focusses on control and feedback. This research analyses a fatal collision involving a van and a train at a level crossing. Accimap, STAMP CAST and PCM are going to be used to analyse this collision. The main output to the use of these three methods will be the identification of the safety interventions to improve the level of safety at the level crossing.

2.5.1. Accimap used the following six risk management framework levels:

- Government policy and budgeting
- Regulatory bodies and associations;
- Local area government planning and budgeting;
- Company management;
- Technical and operational management,
- Physical processes and actor activities; and
- Equipment and surroundings.

2.5.2. STAMP -CAST: Systems Theoretic Accident Model and Process- Causal Analysis using systems theory

Stamp-Cast is an incident analysis technique based on the premise that system failures result from insufficient control or enforcement of safety constraints, and from inadequate feedback mechanisms (Hamim et al., 2022). STAMP-CAST looks at the systems levels and then identify dysfunctional linkages between them.

The following are the steps that are followed when STAMP-CAST is developed:

1. Identify actors and organisations that are controlling the system and
2. Identify controls and feedback mechanisms that exist between different levels of a system.

2.5.3. The Perceptual Cycle Model (PCM)

Perceptual Cycle Model (PCM) represents the view that human cognition is reciprocally related to a person's interaction with the world (Hamim et al., 2022). The police reports, information from print media, online portals and witness interviews were used to generate three PCM's for the incident. These three models are linked to the van driver, train driver and a security guard. The analysis included the events and activities moments before the collision took place. The thought process of the individuals involved in an incident was constructed through the interviews conducted with the train driver, security guard, van driver and passengers/commuters. The interviews focused on the factors and events that influenced their decisions. The constructed thought processes were thematically coded based on the categories of perceptual cycle model, i.e., SCHEMA, ACTION, and WORLD (Hamim et al., 2022). According to the world section, the level crossing did not have booms, traffic signs, markings and flashing lights. Basically, PCM looks at the human performance.

2.5.4. Swiss Cheese Model

Trains are beginning to become a number one choice for both middle and upper class in Indonesia. To reduce the accidents, it is important to understand the root causes. Swiss cheese model is used as a framework accident investigation (Suryoputro et al., 2015). In Indonesia most accidents are slip, train on train and train on vehicle collisions. There are four factors to be considered for a train accident, namely:

1. Maintenance System.
2. Shift System.
3. Crossing System between rail and other road vehicles and
4. Warning System.

The layers of Swiss Cheese model should be determined to understand the overall system of trains in Indonesia (Suryoputro et al., 2015).

Between 2004 and 2010, Indonesia recorded a total of 700 terrific accidents in which 75% was slip accidents, 5% are collisions between trains and 20% are collisions between trains and vehicles at level crossings. These accidents resulted in 367 deaths, 654 serious injuries and 607 minor injuries. Looking at the number of occurrences, it is necessary to prevent occurrences by identifying the root causes using accident model. Accident models show the relationship between the causes and effects. The foundation of the model was using productive system with five layers of Swiss Cheese slice namely:

1. Inadequate defences;
2. Unsafe acts;
3. Psychological precursors of unsafe act;
4. Line management deficiencies; and
5. Fallible decisions (Organizational Influence).

The United Kingdom is the developed country that is being compared to Indonesia. Accidents can be described as the unexpected event and or unwanted outcome that is caused by technological system failure and more than just a result from a chain or sequence of events. Some train accident causes can be related to train length, and some are completely independent of the train length. It has been found that the likelihood of train accident is a function of track class. The severity of the accident depends on the length of the train (Suryoputro et al., 2015). According to the Swiss Model, hazards are represented by the holes, that can appear in every layer. These holes/hazards can change in shape and size. To overcome the holes/hazards there should be built defences.

The Swiss Cheese model can be used to serve three different purposes namely:

1. To be used as a conceptual framework. Occurrences materialize due to failures of the defences at different levels of the system.
2. To be used as a means of communication. It can be used as a framework for accident investigation.
3. To be used as the basis for analysis.

Design of Study:

1. Decide on the type of accidents that will be used for your research.
2. Decide on the research tool (i.e., Swiss Cheese Model) that will be used to analyse the accidents.

2.6. Railway operations and safety in Indonesia

To reduce the occurrences, involvement of all the stakeholders like local government, the ministry of transportation, and rail operator is essential (Iridiastadi, 2016). Methodologies used to understand the root causes and a Fatigue Management System (FMS) need to be developed. At least 4,4% of the total incidents is train collisions, 35% is human factor related. The common fault is a train controller who gives a wrong signal number to the train driver and train drivers falling asleep while operating the train. Getting to the root causes of the incidents is still a challenge. High level of monotony may lead to sleepiness. Fatigue and sleepy controllers play a major role in incidents. The investigations did not identify the root causes. Fatigue management system to be implemented and the emphasis should be on train drivers and controllers. Rosters must be strictly followed.

An article on fatal accidents on Europe’s railways focused on fatal train accidents where the term ‘train accident’ referred to accidents in which moving trains are damaged, and persons (either inside or outside trains) may be killed or injured. This definition includes collisions, train derailments and train fires and is not specific to collisions. While fatal train accidents account for a minority of railway accidents, they are important because a single train accident can cause multiple fatalities (Evans, 2021). A notable finding is that the proportion of accidents caused by signals passed at danger (SPADs) fell from 40% in 1990 and 1999 to 21%.

Fatal train wrecks and derailments can result from intricate patterns of events, and there may be several ways they may have been avoided. Additionally, any contributing factor may have many antecedents. These are the focus of accident investigations, which may provide a variety of safety recommendations to lessen the incidence or effects of accidents of a similar nature.

The most common cause of accidents is Signals Passed at Danger (SPAD), which account for 70 of the 211 accidents with known causes (33%). The second most common cause is over-speeding (16%), and the **third is signalling or despatching errors (15%).** Signalling or despatching errors occur typically when a signaller or station staff member authorises a train to proceed, but its path conflicts with that of another train.

3. Methodology

The data collection approach for this study made use of qualitative and quantitative data collection methods. The quantitative data collection procedure included the:

- review of collisions statistics provided by TFR and PRASA, through the state of safety report ;and
- distributing questionnaires to relevant TFR and PRASA employees.

The qualitative data collection approach included the:

- collection and analysis of the abnormal working systems (as stipulated in the train working rules);
- conducting interviews with personnel from TFR and PRASA,
- the analysis of abnormal working systems used internationally through articles and journals;
- identification of risk mitigation methodologies used by similar international rail commuter operators, conduction of a task analysis and observation;
- analysis of the sections under abnormal working (sections where manual train authorizations are executed) over a period;
- collection and reviewing of collision investigation reports compiled by the RSR;
- Task analysis and observation at CTCs visited; and
- Each of the sampled investigation reports was analysed according to Edkins and Pollock, 1997 to determine the factors that led to its outcome, and the latent organisational factors involved in the accident.

1. The factors that led to its outcome:
    - Time of occurrence;
    - Details on the occurrence;
    - The direct and root causes;
    - Contributory factors; and
    - Key contributory factors.

2. The latent organisational factors involved in the accident:
    - Faulty equipment;
    - Poor communication;
    - Training deficiencies;
    - Vacancy issues;
    - Lack of supervision;
    - Shift cycles;
    - Maintenance failures;
    - Fatigue and stress risk and
    - Visibility issues.

4. Results and Discussion

4.1. Data Analysis

Analysis of Investigation Reports and Board of Inquiry Investigation Reports conducted by the RSR.

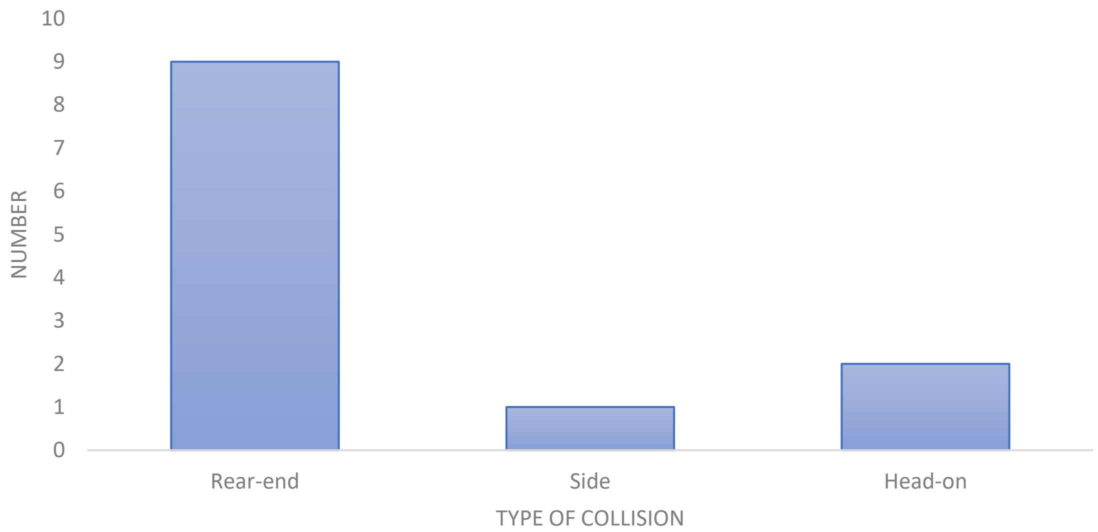

Figure 3: Analysis of BOI investigation reports

Figure 3 above indicates that out of the twenty-nine (29) collision investigation reports that were analysed as seen on Annexure 1 only twelve (12) collisions occurred under abnormal working. The 29 collision investigation reports came from the period 2010/2011and 2020/21. The rear-end collisions accounted for the highest collision type recorded in the years under review. Head-on collisions, while significantly fewer, accounted for the next highest number of collisions at 2. The lowest recorded type of collision was the side collision.

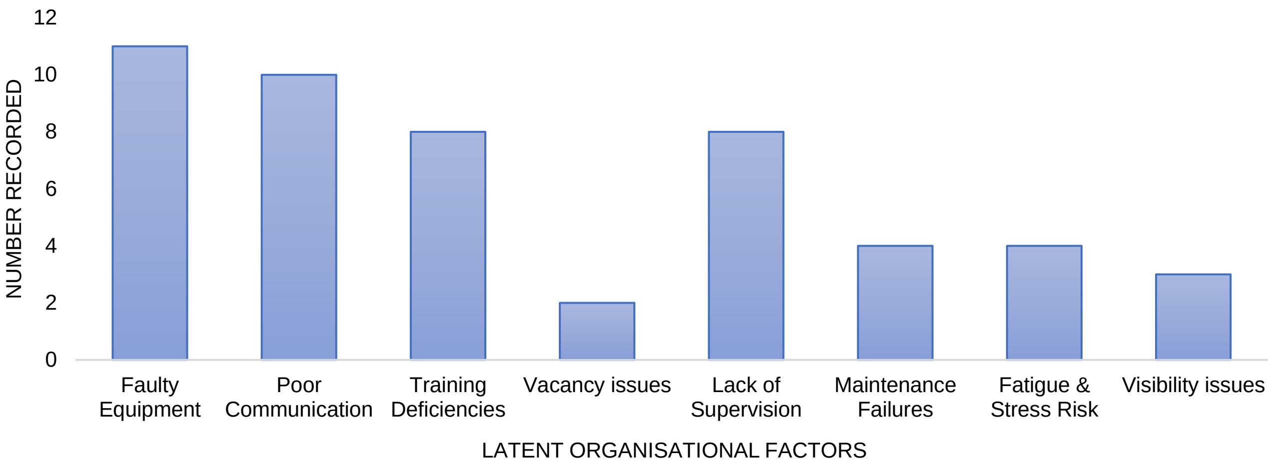

Figure 4: Latent organisational factors during occurrences with abnormal working

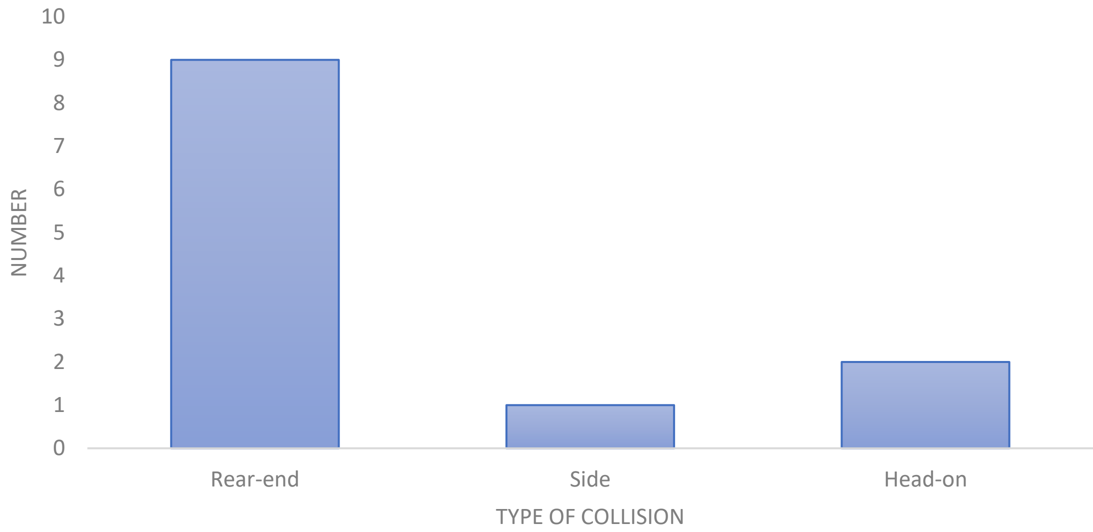

Figure 3:Indicates 12 train collisions occurred under abnormal conditions/ abnormal working.

The main causes for the collisions are faulty equipment, poor communication, lack of supervision and training deficiencies, were the 4 highest noted latent organisational failures. Of those 12, faulty equipment was found to have been present in 11 of these occurrences. Poor communication was noted in 10 of the 12 occurrences. Lack of supervision and training deficiencies were noted as organisational failures in 8 out of the 12 cases each. Vacancy issues was the least noted failure.

4.1.1. Investigation Reports

The analysis of the investigation reports conducted by the RSR indicated that there is no standardised format of conducting investigations. This is ubiquitous in most of the investigation reports where the direct causes and root causes are not clearly defined. What can be assumed is that the investigators experience, and knowledge contributed to the outcome of the investigation conducted. It might then be important to consider utilising the system thinking within the RSR as alluded by the utilisation of the Socio-Technical System (STS) theory. This theory distinguishes the difficulty of the interface between people and technology in workplaces that will assist with conducting investigations that will bear relevant and precise results. The STS theory used is system thinking. System thinking as defined by interrelation and working of constituent parts over time, and appreciation that changing one part will affect other parts.

- It's important that blame is not apportioned to human error however utilizing the "just culture" to look at the whole system and fixing where there are problems that lead to human error such as workload analysis.
- The lack of identification of system level influencers that require change to reduce the potential of human errors. It is important that systems installed reduced the possibility of a human error from occurring.
- The investigations conducted show that the outcome report is dependent on the person who conducted the investigation such as experience, having worked in the environment and how many time they have conducted investigations.
- The outcome of the investigations varied, and the actual root causes were not clear in some investigation report.
- A proposal was given to standardize the investigation reports after the analysis of various reports.

The analyses of the investigation reports have been grouped into these categories as stated by the utilisation of the HFACS that is implemented in the aviation environment. The technique categorises the accidents causes into four level of factors namely unsafe acts, preconditions for unsafe acts, unsafe supervisory and organisational influences as stated by (Shappel and Wiegmann, 2000). The technique is based on the "'Swiss Cheese' model of accident causation in which an accident occurs due to failures that run through holes that are aligned across several layers of defence mechanisms.

Table 1: Human Factor and Classification System (HFACS)

INVESTIGATION REPORTS	UNSAFE ACTS	PRECONDITIONS FOR UNSAFE ACTS	UNSAFE SUPERVISORY	ORGANISATIONAL INFLUENCES
1.	Both trains were authorized on the same line without ensuring that the leading train had cleared the section.	Poor execution of SD2 manual authority during abnormal working and non-compliance to Train Working Rules.	There was no supervision.	Lack of enforcement of following the SD2 Manual train authorisation and train working rules during abnormal working and refresher training.
2.	Failure of the driver of train 8466 to obey the instruction to proceed on sight and stop at a safe distance from where the train 9458 has failed.	Lack of following of the requirements stipulated by the Train Working Rules to protect the train when it has failed in the section. Poor communication between the driver and the TCO	There was no supervision.	Lack of mitigation measures when enforcing the Train working rules and fatigue and stress management.
3.	Tamping machine collided side on with train 1183 when it did not adhere to the rules and procedures of safe working.	Poor maintenance of trains that lead to failure in the section.	There was no supervision.	Lack of monitoring of maintenance conducted.

INVESTIGATION REPORTS	UNSAFE ACTS	PRECONDITIONS FOR UNSAFE ACTS	UNSAFE SUPERVISORY	ORGANISATIONAL INFLUENCES
4.	Miscommunication in terms of which train must move first.	Lack of supervision when absolute working is taking place.	There is no supervision.	Lack of training.
5.	Miscommunication between the TCO and the train driver.	Lack of enforcement of the speed restriction during abnormal working	There was no supervision during issuing of abnormal working	Lack of acquiring spares when signalling cables and equipment that were vandalised.
6.	Train driver passed signal at danger exceeding the authority issued by the TCO. The driver could not control the train (speeding);	Lack of adherence to the rules for the TCO and Train driver	There was no supervision	Lack of maintenance, training and equipment utilised was faulty.
7.	Train passed signal at danger without authority & collided with the rear of a stationary train.	Lack of maintenance on the panel and the trunk radio network.	There was no supervision.	Lack of maintenance on panel and trunk radio; Lack of training.
8.	Faulty equipment due to cable theft.	Lack of managing the authority sequences.	There was no supervision.	Lack of stress and fatigue management for the TCO, Lack of training

INVESTIGATION REPORTS	UNSAFE ACTS	PRECONDITIONS FOR UNSAFE ACTS	UNSAFE SUPERVISORY	ORGANISATIONAL INFLUENCES
9.	Lack of declaring the section as occupied when the load was left on the section. Lack of proper handover between the Train driver and TCO and the following shift TCO.	A substandard handover process was followed between TCOs and Driver. Missing consignment document given to the driver by TFR to ensure that the correct load information is in place.	There was no supervision	Lack of updated handover process and lack of training.
10.	Lack of handover process between the TCO and train driver.	Lack of protection of the load when its staged.	There was no supervision.	Lack pf enforcement of the handover process and Train working rules on protecting the load when staged.
11.	Signal passed and danger; Lack of handover process between the train driver and TCO on the failure of the train; Train driver not adhering to the speed allowed in the section.	Lack of adhering to the train working rules.	There was no supervision.	Lack of enforcement of adhering to train working procedures.

INVESTIGATION REPORTS	UNSAFE ACTS	PRECONDITIONS FOR UNSAFE ACTS	UNSAFE SUPERVISORY	ORGANISATIONAL INFLUENCES
12.	Train 9457 was erroneously authorised onto an occupied line. The panel hand over process between TCO's which was accompanied by an instruction to authorise Train 9457 was done improperly and contrary to Train Working Rules.	Lack of adhering to train working rules.	There was no supervision.	Lack of maintenance of signalling equipment damaged through theft and vandalism. High number of vacancies in the CTC. Lack of stress and fatigue management.
13.	Failure of a signalling module that led to incorrect information relayed to the TCO on the track occupation status.	Lack of proper maintenance on the signalling equipment that led to incorrect.	There was no supervision on the signalling maintenance department to verify the functionality of the signalling equipment.	Lack of training and following of maintenance guidelines to ensure equipment is fixed properly.

The results of the HFCAS indicated that the unsafe acts ranged from non-adherence to train working rules, signal passed at danger, failure to maintain faulty equipment, lack of following the handover process, miscommunication between the train driver and TCO due to faulty trunk radio network and misunderstand of the authority given. The supervisory factor referred to incidents where there was no supervision in all the collisions that took place. The last factor, which is the organisational factor, referred to the lack of enforcement of rules and processes.

The assessments highlight the importance of systematic interventions that are directed to the procedural aspects and organisational policies and climate as stated by the situation analysis (Shappel and Wiegmann, 2000) that will decrease the number of railway accidents.

According to (Gordon, 1996), organisational factors are often linked to an organisation's safety culture or climate or other elements that have an impact on the safe working environment. These failures, indicate that the organisations involved had a potentially negative safety culture and poor management processes. It indicates that imbedded within the organisations involved in these collisions is a practice of wilful violation of safety standards and practices. Ultimately though, the procedures put in place were unable to serve a regulatory function over the process of safe operations.

Abnormal working as a practice, is often accompanied by different working procedures. These will usually include a different set of tasks reserved for emergency situations. Some of these tasks require additional resources to execute. Therein lies the potential of increased risk, particularly if the safe working methods employed during abnormal working do not adequately address safety risks or provide adequate safety defences. Additionally, existing weaknesses in the safety procedures and practices will be exasperated by the implementation of new working practices that either replace the standard ones or are added to them. For instance, if an operator ordinarily contends with faulty equipment, communication breakdowns, supervisory inadequacies, training deficiencies etc., the implementation of a working method that removes some of the safety defences imbedded in the system (whether due to a complete failure of parts of the operational system such as the blackout of the visual display units due to signalling cable theft or the breakdown in telecoms equipment removing the use of trunk radios) will lead to a highly unsafe system when a temporary working method is implemented that has fewer defences and is more reliant on the weak parts of the system.

Figure 4 shows that faulty equipment failures were the most recorded failure types. This is in line with the general finding that abnormal working was often associated with infrastructure related equipment failures. Some of the equipment failures were related to theft and vandalism of critical infrastructure and others were related to poor maintenance practices resulting in the breakdown of equipment/assets. The results show that poor communication was among the top 4 commonly occurring failures. It follows that a breakdown in communication – vital during train authorizations – when abnormal working is initiated could result in catastrophic outcomes. The presence of lack of supervision and training deficiencies are among the top four noted latent organisational factors also tracks as some of the collisions occurred because of an incorrect decision made or an unintended action executed; it tracks then that having a supervisor present monitoring safety activity could have acted as a safety barrier, possibly avoiding the occurrence.

There were no instances of shift cycles failure noted and fewer instances of vacancy issues, maintenance failures, fatigue and stress risk and visibility issues noted during the analysis of the investigation reports. The finding about the fewer instances of visibility issues is aligned with the circumstances that led to the collisions; the fewer instances noted of vacancy issues, maintenance failures, fatigue and stress risk does not track as well. This is because these factors are often related to the top four failures noted. For instance, a TCO who makes an incorrect decision may indeed need additional training and supervision; this same TCO may however have made a different decision, perhaps not made the same decision if they were not under extreme stress or fatigued.

The fewer instances noted during the analyses may have been influenced by investigator bias; each of the investigation reports were conducted by different personnel; the difference in personnel may have meant that some focused more on certain aspects and less on others.

4.2. Interviews conducted with Pretoria North CTC Train Control Officers and Section Managers

The interviews were conducted on the 15th of November 2022 with Train Control Officers, Section Managers and Coordinators. The same questionnaires were then completed by the rest of the Pretoria North CTC staff. Their responses were then plotted. The questionnaire is attached under Appendix 2.

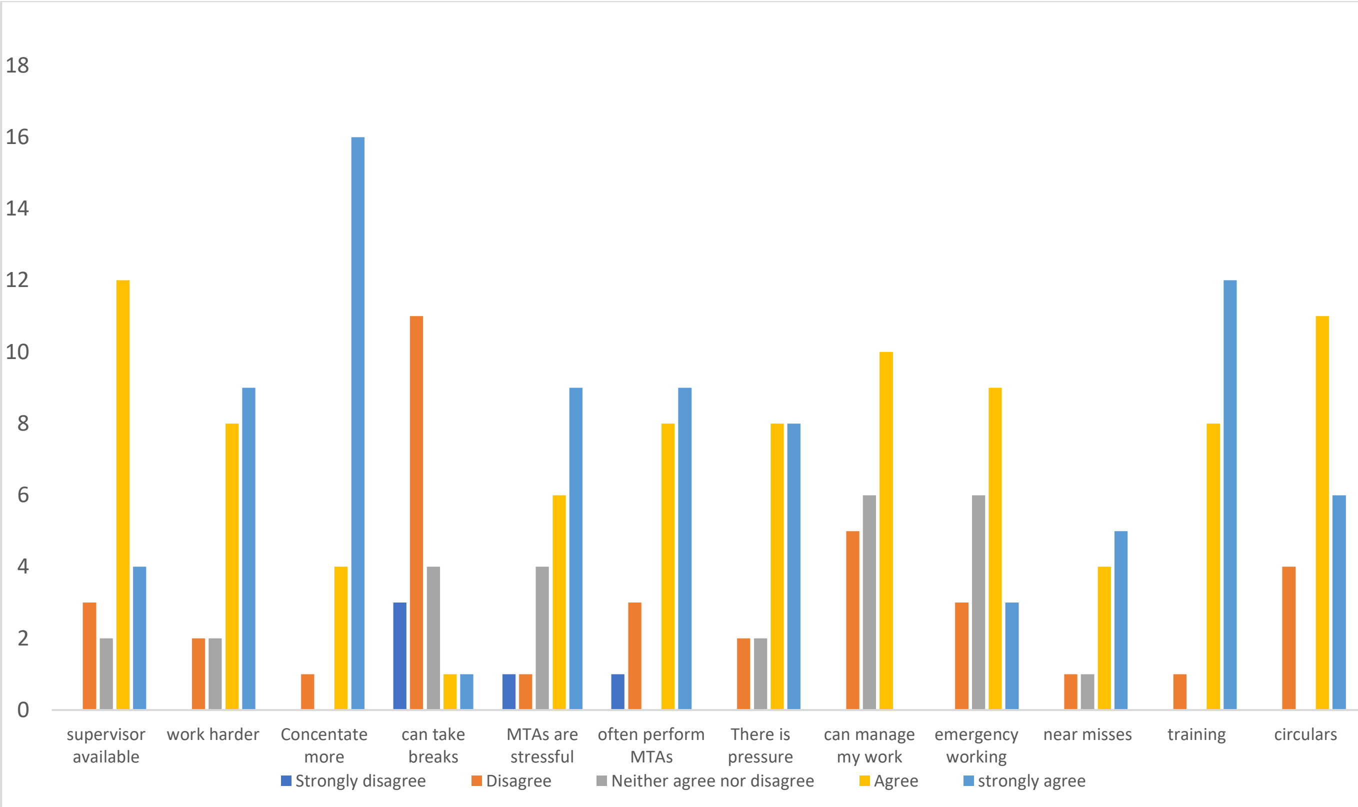

Figure 5: Responses from the interviews conducted at Pretoria North CTC

Based on Figure 5, 76,2% of the respondents, indicated that more concentration is required when performing manual train authorizations. The required concentration coupled with long working hours result in fatigue which in turn result to an increased probability of error when executing manual train authorizations. The signalling systems have been unavailable for several years due to theft and vandalism. Hence the abnormal working has become a normal way of working. Based on the responses from the interviews, 43% strongly agree that they often perform manual train authorizations and 38,1% agree that they normally perform manual train authorizations.

Table 2: Manual Train Authorisations conducted at Pretoria North CTC per person per shift.

Respondents	Manual Train Authorizations per person per shift
Respondent 1	100
Respondent 2	80
Respondent 3	100
Respondent 4	100
Respondent 5	70
Respondent 6	30
Respondent 7	100
Respondent 8	200
Respondent 9	100
Respondent 10	60
Respondent 11	50
Respondent 12	30
Respondent 13	100
Respondent 14	100
Respondent 15	100
Average	**88**

On average each TCO performs 88 manual train authorizations per shift (refer to Table 2).19% of the respondents strongly agree that there is supervision by the Section Managers and Coordinators and 57% agree (refer to Figure 5). Supervision can assist in keeping the TCOs vigilant throughout the day and based on the interviews feedback, there is still room for improvement with regards to supervision.

43% of the respondents strongly agree that performing manual train authorizations is stressful and 29% of the respondents agrees that performing Manual Train Authorisations (MTA) is stressful (refer to Figure 5). A lot still needs to be done to manage the stress due to performing manual train authorizations.

When asked if they do take breaks, 52% strongly disagree and 14% strongly agree. The TCOs don’t have breaks like lunch breaks, they are allowed to take breaks as and when there is low traffic volume such as off-peak periods therefore TCO’s are expected to be on their workstation throughout their shifts.

The Introduction of emergency working has been effective in reducing the number of manual train authorizations performed however 14% strongly disagree with this and 29% disagree.

Training of the TCOs is taking place. 57% strongly agree that training is taking place and 38% agree. While 52% agree that the circulars are discussed with the TCO by the Coordinators, 19% strongly disagree. It shall be noted that refresher training is no longer taking place at Essellen Park (Transnet School of Rail), this offered a refreshing time for the TCO especially as they are performing manual train authorisations.

The trunk radios are not working so telephones and cell phones (by train drivers if the trunk radios are not working) are used (refer to appendix A). About three 3 respondents think 4 minutes radio cut off is adequate for them to finalize manual train authorizations. However, this response is limited as the TCOs hardly use the trunk radio system for authorisations.

4.3. Interviews conducted with Leeuhof CTC Train Control Officers and Section Managers

The interviews were conducted on the 22nd of November 2022 with Train Control Officers, Section Managers and Coordinators. The same questionnaires were then completed by the rest of the Leeuhof CTC staff. Their responses were then plotted. The questionnaire is attached under Appendix 2.

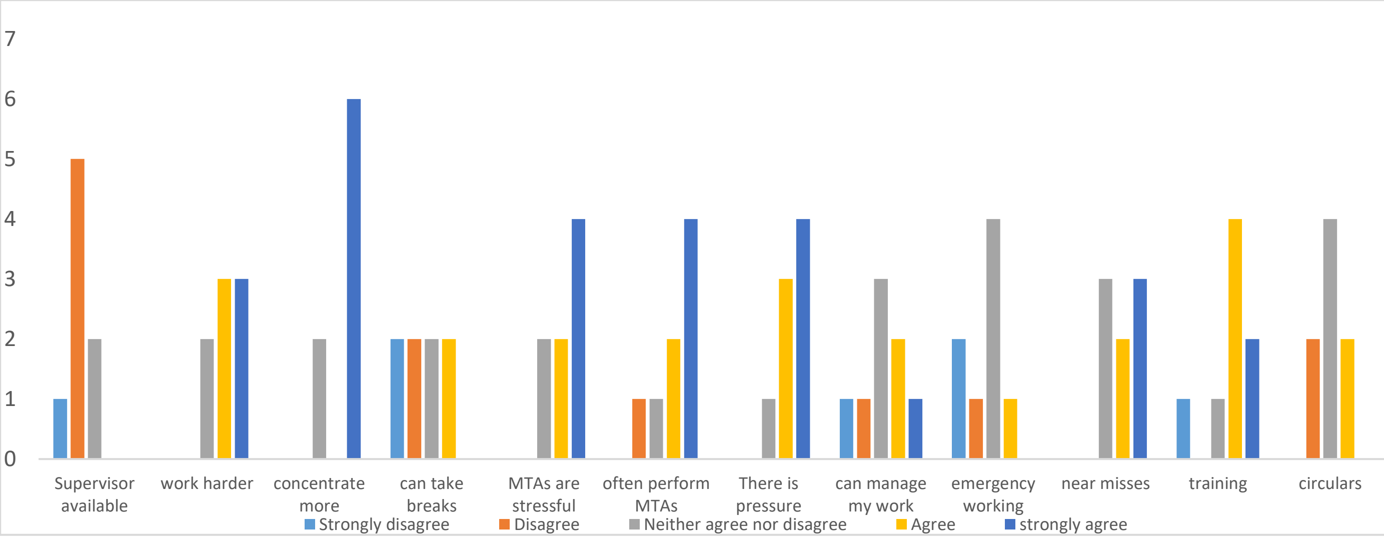

Figure 6: Responses from interviews conducted at Leeuhof CTC

According to the interviewees, 63% disagree that there is supervision of the TCOs by the Section Managers and Coordinators. Poor supervision can lead to TCOs making mistakes when executing manual train authorizations.

Executing the manual train authorizations needs the TCO to concentrate more as they need to constantly keep track of the train whereabouts to avoid sending more than one train in a section and they also need to ensure that there are clear and unambiguous communication between themselves and the train drivers. A total of 75% of the respondents agree that performing manual train authorizations require their undivided concentration (refer to Figure 6). Performing more than 100 manual train authorizations per shift and working for long hours without taking breaks can be stressful to the TCOs. A total 50% of the respondents feel that executing manual train authorizations is stressful.

4.3.1. The responses on the questionnaires

- A total of 75% of TCOs feel they work harder when performing manual authorization than when everything is working normally, while 25% neither agrees nor disagrees. This indicates that manual authorization makes TCOs work harder than usual.
- Supervisors are not available while TCOs are conducting abnormal working. According to the respondents, 50% do not agree or disagree with the availability

of supervisors during abnormal working hours, while 25% disagree and 25% agrees that supervisors are available during abnormal working.

- With regards to concentration during abnormal working, practically all respondents agree that they need more concentration while working abnormal working. 75% strongly agrees with 25% neither agreeing nor disagreeing.
- A total of 50% of the respondents strongly agree that performing manual authorization is stressful.
- A total of 75% of the respondents stated that they perform manual authorisation almost all the time, while 12,5% are unsure and 12.5% disagrees that they often perform manual authorization.
- A total of 88% of the respondents agrees that there is a lot of pressure when performing manual authorization.
- TCOs have been conducting abnormal working for several years, and it is considered that therefore 37.5% are unsure whether they can manage their work efficiently when performing manual authorisation. Simultaneously, 37.5% believe they can handle their tasks very well during manual authorization. 25% of respondents disagree that they can manage work well during unusual hours.

Table 3: Manual Train Authorizations conducted at Leeuhof CTC per person per shift

Respondents	Manual Train Authorizations per person per shift
Respondent 1	300
Respondent 2	100
Respondent 3	250
Respondent 4	300
Average=	**237,5**

On average each TCO performs 238 manual authorizations per shift (refer Table 3) and 50% of the respondents agree that they often perform manual train authorizations. Introduction of emergency working results to reduced manual train authorizations as the trains are authorized over long distances since several signals is crossed and points machines are clamped.

A total of 50% of the respondents believe that the introduction of emergency working leads to reduction of the number of manual train authorizations. To help the TCO improve their work performance they must undergo training and refresher training at least annually. 50% of the respondents agree that they attend training. The changes in train operations are communicated using the circulars. The circulars are then clearly communicated with the TCOs by the Section managers/ Coordinators. 50% of the respondents agree that the circulars are communicated with the TCOs.

Taking breaks is necessary, especially if one is performing strenuous work as issuing manual train authorizations, 25% of the respondents strongly disagree when asked if they are allowed to take breaks.

The feedback from the interviews is that 4 minutes cut off time for the radios is adequate however few interviewees thinks that due to poor network coupled with load shedding, 4 minutes is sometimes not adequate.

4.4. Interviews conducted with Sentrarand CTC Train Control Officers and Section Managers

The interviews were conducted on the 29th of November 2022 with Train Control Officers, Section Managers and Coordinators. The same questionnaires were then filled by the rest of the Sentrarand CTC staff. Their responses were then plotted. The questionnaire is attached under Appendix 2.

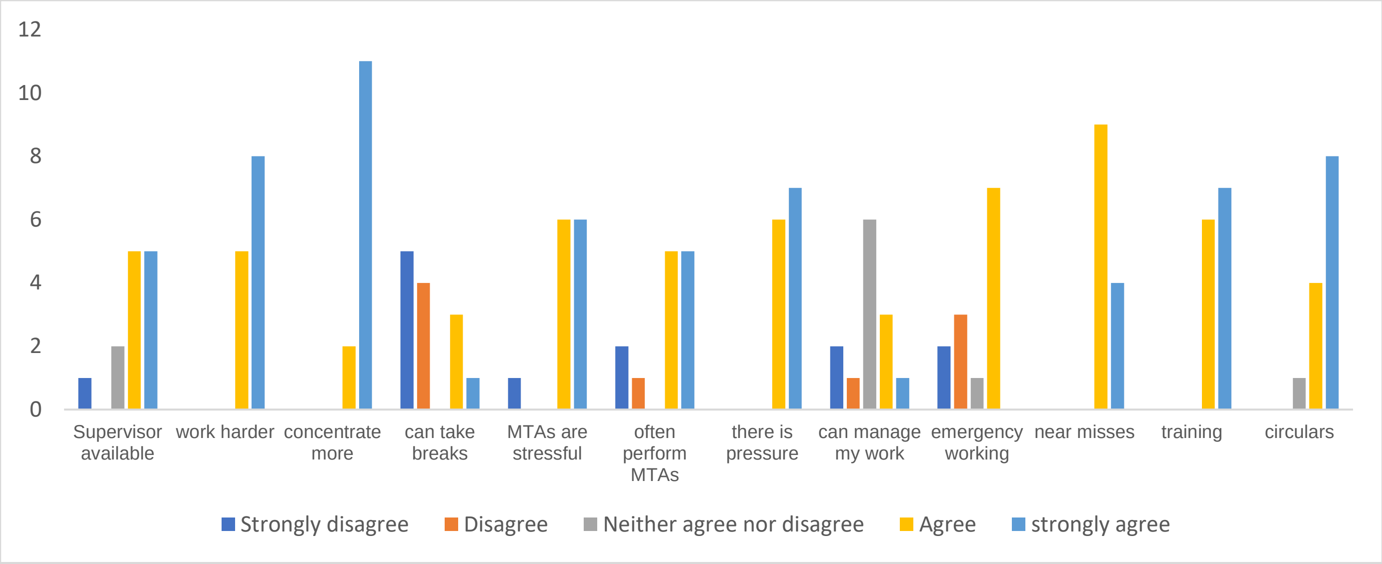

Figure 7: Responses from the interviews conducted at Sentrarand CTC

Coordinators must supervise and observe the TCOs to ensure they do not commit mistakes when executing their work. According to the feedback from the interviews, 38,5% strongly agree that the Supervisors are always available when they are executing manual train authorizations and the other 38,5% agrees.

Issuing manual train authorizations can be strenuous as they require the TCOs full concentration. In the absence of track and points indications, the TCO doesn't know where the trains are in a section so the TCOs rely on their memory and the markers on the panel to tell where the sections are occupied or not and the train drivers have to ensure that the points are lying correctly for their movement. This is indeed strenuous which is why 84% of the respondents strongly agree that they need to concentrate more when they are executing manual train authorizations and the other 15,4% agree (refer to Figure 7).

Issuing manual train authorizations without breaks throughout the day is very risky as the TCOs can become fatigued and make mistakes which can potentially lead to train collisions. Feedback from the respondents confirms that 38,5% strongly disagree that breaks are taken during their shifts and 30,8 agrees. A total of 46,2% of the respondents strongly agree that issuing the manual train authorizations is strenuous and the other 46,2% agrees. Clamping of points and crossing of some signals increases the length of sections over which the trains are authorized and hence reduces the number of manual authorizations.

According to the respondents, 54% strongly agree that the emergency working reduces the number of manual train authorizations however 23,1% disagree. So, the introduction of the emergency working still needs to be improved to ensure that they significantly reduce the manual train authorizations.

Table 4: Manual Train Authorizations conducted at Sentrarand CTC per person per shift

Respondents	**Manual train authorizations per person per shift**
Respondent 1	160
Respondent 2	180
Respondent 3	100
Respondent 4	50
Respondent 5	125
Respondent 6	125
Respondent 7	180
Respondent 8	100
Respondent 9	200
Respondent 10	150
Respondent 11	50
Respondent 12	50

Average	**122,5**

On average, 123 authorizations are executed by each TCO per shift (refer to Table 4). Training and refresher training are being conducted at Sentrarand with 54% strongly agreeing that training is attended and 46,2 % agreeing. The circulars and the changes in the operations are communicated with the TCO. A total of 62% of the respondents strongly agree that the circulars are well communicated and 30,8% agree (refer to figure 3). The feedback from the interviews is that 4 minutes cut off time for the radios is adequate however few interviewees thinks that due to poor network coupled with load shedding, 4 minutes is sometimes not adequate.

4.5. Task Analysis and Observation Summary

The CTCs observed were similar in structure: they generally had several TCOs working at different workstations in one large room. The TCOs at each of the workstation are responsible for different lines, working in parallel with one another.

TCO duties are typically performed indoors at a computer workstation. The task primarily includes computer use with some note taking on physical documents. The TCOs at the CTCs visited were meant to use a colour light system on the CS90. This system, when functional, is meant to grant routes with functional signals. The task is primarily cognitive with minor physical elements. The computers used included several screens that displayed train activity and track usage information through video display terminals. The TCOs are meant to use these displays to conduct remote track switch setup, open a path for trains, or block a section of track to safeguard infrastructure personnel or other passing trains. The job of a TCO requires that they coordinate with each other (as TCOs), coordinate with train drivers, section managers, yard officials, signal technician, security personnel, etc. to ensure smooth train operation without delays. They are meant to primarily communicate through radio systems with the phone being used occasionally.

The CTCs visited were meant to work in the straightforward manner described above, they however did not work in this manner. They worked in a manner described as abnormal working because they, instead of using the display terminals to authorize trains and radio systems to communicate with the relevant personnel, they used documents to track where trains where and the phone to communicate. Abnormal working, as a start changes 2 key fundamental activities of a TCO.

The tables below are a summary of the different sub-tasks that were executed by TCOs working in abnormal working environments. The tables depict the sub-tasks required to execute the primary task of authorising trains during normal working (using the displays) and during abnormal working (manually authorising trains and using phones to communicate).

The table below depicts the sub-tasks required recorded at PRASA:

Table 5: Tasks and sub-tasks at PRASA CTC

Task	Sub-tasks during Abnormal Working	Sub-tasks during Normal Working
Sign-on	Sign on duty and complete fitness for duty form	Sign on duty and complete fitness for duty form
	Participate in green area safety talk	Participate in green area safety talk
	Handover procedure and sign on	Handover procedure and sign on
Authorise Trains	Verbal alerts from other TCOs about oncoming trains	Click onto CS90 system for access
	TCO makes notes	Watch screen and authorise trains as needed
	Train Driver (TD) calls to verify where they are	Note train information on the train register
	Note train information on the train register	
	Prepares authority by checking the schedule and confirming the train information	
	Records this in the authority register	
	Call TDs back to give them the authority	
	Completes details recorded in train register	
Pre-shift	Section manager goes out to clamp points	

Table 5 shows that there are a lot more sub-tasks required during abnormal working compared to normal working. The TCOs indicated that they had no scheduled breaks worked into their roster, they made time for breaks by giving each other an opportunity to eat their lunches. It is evident from the table above that the sub-tasks during abnormal working was heavily reliant on accurate note taking; this may imply that the TCOs must be engaged and focused significantly more during abnormal working because of this.

The table below depicts the sub-tasks required recorded at TFR:

Table 6: Tasks and sub-tasks at TFR CTC

Task	Sub-tasks during Abnormal Working	Sub-tasks during Normal Working
Sign-on	Sign on duty and complete fitness for duty form	Sign on duty and complete fitness for duty form
	Participate in green area safety talk	Participate in green area safety talk
	Handover procedure and sign on	Handover procedure and sign on
Authorise Trains	Log into CS90 system (uses some aspects of CS90)	Click onto CS90 system for access
	Verbal alerts from other TCOs about oncoming trains	Watch screen and authorise trains as needed
	Enters details into the CS90	Note train information on the train register
	Find numbers for TDs to call them	
	Call TDs to verify where they are/TD calls to verify where they are	
	Note train information on the train register	
	Inform TD of clamped points and which points need cranking; driver repeats instruction	
	Organise security to accompany TDs where points need to be cranked	
	Calls TD back	
	TD confirms points that were cranked	
	Give TD authority	
Pre-shift	Section manager goes out to clamp points	

Table 6 shows, like the table before, that there are an increased number of sub-tasks required during abnormal working compared to normal working. The TCOs indicated that while risk assessments had been done in their environment, no workload assessments had been conducted recently. The TCOs visited also revealed that they and the train drivers regularly got confused about which direction was negative and which one was positive at the points; TCOs often had to explain which way is negative and which one is positive to ensure that the points were set correctly. When asked about the tendency to have to call the train drivers, they specified that it was a challenge and that the phones that they used did not assist since they did not show numbers of incoming calls. They, like the PRASA TCOs, revealed that they were not allocated time for breaks in the roster.

The work of TCOs is highly specialized, requiring attention to detail, communication, coordination, and extensive planning. Train control is already a cognitively challenging task that requires a great deal of focus, coordination, and planning, it is no wonder that the addition of abnormal working (where they cannot rely on the systems necessary for them to execute their duties) presents unique and challenging risks that increase task demand and mental load. The information included in the tables above and the findings from the interviews suggest that the nature of abnormal working and the way that it is managed increases the cognitive difficulty of the job of a TCO. It appears to require dynamic re-planning that is continuous and that places a high cognitive demand on TCOs.

5. Conclusions

The research was aimed at evaluating the link between abnormal working and train collisions. PRASA and TFR investigation reports (29 in total) were analysed and the TCOs, Coordinators and Section managers from Pretoria North CTC belonging to PRASA, Leehof and Sentrarand CTCs belonging to TFR, were interviewed using the developed questionnaire (refer to annexure 2) and task analysis conducted at the CTCs. Referring to **Figure 4**, the human factor related latent organizational factors like training deficiencies, vacancies lack of supervision and fatigue and stress risk contributed 22 times, compared to the 50 times by all the latent organisational factors, towards the 12 train collisions that occurred during abnormal working. Hence it can be concluded that the human factors strongly link the abnormal working to the train collisions.

Based on **Figure 5, Figure 6, Figure 7**, the CTC staff interviewed at three CTCs strongly agree that executing Manual Train Authorisation (MTA)s require more concentration and it is more stressful. The stressful nature of executing MTAs can easily lead to fatigue and increased probability of a TCO issuing an authority to the train driver to enter a block that is already occupied which can possibly lead to a train collision. As far as the results from the interviews were concerned, it can be concluded that an increase in the number of sections under abnormal working can lead to an increased number of train collisions hence, abnormal working is directly proportional to the train collisions.

6. Recommendations

6.1. Recommendations (emanating from the literature review)

- Sections where trains are authorised must be reported to the RSR r and adequate risk assessment identifying and mitigating the risks associated with MTAs must accompany the submissions.
- To ensure that the fall-back system does not become a primary system, the RSR must specify the period the operator is allowed to perform MTAs. If the stipulated period is exceeded, the prohibition directives should be issued.
- Operators to use a combination of incident investigation methods/models to identify the incident root causes.

6.2. Recommendations (emanating from the interviews and investigation reports analyses)

- The vacant positions must be filled and both PRASA and TFR must consider having double shifts to ensure that the TCOs performing manual train authorizations are not fatigued.
- Emergency working to be rolled out to all the sections under abnormal working. This will result to significant reduction of the manual train authorizations.
- Allow the TCO breaks of 30minutes at least every 3 hours.
- PRASA to record the manual train authorization in a computer system that can warn TCOs of any conflicting manual train authorizations.
- The utilization of an electronic manual train authorisation system utilized by TFR may be beneficial to PRASA to reduce the paperwork completed by the TCO and it keeps track of the actual number of authorisations and provides fallback plan to ensure that multiple train will not be authorised in the section.
- The trunk radios must be fixed to improve communication between the TCOs and Train Drivers.
- Expedite the re-instatement of the signalling systems.
- A standardised format of conducting investigations to be adopted.
- Adoption of systems thinking within the RSR (as alluded by the utilisation of the Socio-Technical System (STS) theory).
- Root causes in the investigation reports should be clearly defined.

- It might then be important to consider utilising the system thinking within the RSR as alluded by the utilisation of the Socio-Technical System (STS) theory.
- A proposal was given to standardize the investigation reports after the analysis of various reports.

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ANNEXURE 1: Investigation Reports on Collisions

No.	DETAILS	DIRECT CAUSE	ROOT CAUSE	CONTRIBUTING FACTOR	KEY CONTRIBUTING FACTOR	ABNORMAL WORKING
1.	On the 9th of January 2018 at approximately 7h35, train 0323 collided into the rear end of train 0317 at Geldenhuis station	Both trains were authorized on the same line without ensuring that the leading train had cleared the section	Poor execution of SD2 manual authority during abnormal working and non-compliance to Train Working Rules	Train 0317 failing on the section		Yes
2.	On the 6th of February 2016, a TFR train 8466 (light locomotives) collided into	Failure of the driver of train 8466 to obey the instruction to proceed on sight and stop at a safe	The primary root cause of the occurrence was the failure by the crew of train 9458 to	Train 9458 failing on section	Train driver failing to stop where authorized	Yes

	train 9458 stationed in the section between Hazyview and Numbi stations	distance from the failed train	follow the requirements as stipulated in TWR to protect the train when it failed in the section			
3.	On the 18th of June 2014, the tamping machine was in a side collision with train 1173 which was standing foul at the back in Jubilee	Tamping machine collided side on with train 1183	Non adherence to the train working rules and General Appendix. - Lack of communication	Rules and procedures of safe working were not adhered to		Yes
4.	On the 26th of July 2018 at approximately	The immediate cause of the accident was due	No supervision or anyone to oversee the			Yes

	00h03, two (2) TFR diesel trains (T1282 and T1494) collided near Kalbaskraal station, Western Cape	to miscommunication in terms of which train must move first	absolute working process			
5.	PRASA Train No. 1818 collided with the rear of PRASA Train No. 0810 at the Mountain View station	The immediate cause of the collision was the miscommunication between the TCO and the train driver	The root cause of the collision will only be determined once a full investigation of the collision has been completed	The train driver not adhering to the RSR's speed restriction of 30km/h as well as the authority to proceed on sight during degraded mode • Cables and signalling		Yes

				equipment that were not replaced for an extended period after being vandalized in the section • Lack of supervision of the TCO and train drivers during conditions of manual authorisation		
6.	PRASA train collided with the TLB that was trenching next to the railway line	The trenching exercise was conducted too close to the railway track resulting in the collision of Metro	Management failure to ensure compliance to risk assessments and safety	Crew not informed about occupation (no occupational notice given by TCO) on route and during		Yes

		train 1865 with a TLB	procedures, systems & standards	handover; YQ not issued as expected. TCO was also not aware; Contractors did not comply with safety requirements Contractor did not sign or report to CTC office as expected; no sup was present Induction training on contractors involved did not happen		

7.	Train collided with a stationary train at Brakpan station yard	TD could not control the train (speeding); TCO gave train authority to pass signal at danger when the hand point was set for the occupied line & while the train was moving	Non-adherence of rules and procedures by TD & TCO	Signal cabin voice recording device and signal not functioning; yard master had no authority to travel on the train, TD & TCO did not follow yard workings; train brakes failed; Brakpan working conditions had not been communicated to the TCO; telemeter was not functional ; points not correctly set		Yes

8.		Two (2) trains were authorized into the same section of track at the same time.	Poorly managed manual authorization process and failure by the personnel and supervisors on duty to observe and implement the requirements of abnormal working as stipulated in the train working rules.	Cable theft in the Elandsfontein complex which affected track circuits and signals These preceding events dictated that abnormal working procedures or manual authorisation of trains be introduced in the section between Isando and Elandsfontein stations. Details of what	Hand over process for the shift change at 06h00 was not properly followed PRASA Elandsfontein train control personnel embarked on abnormal working process littered with numerous poor safety defences/uncontrolled risks, routine violations and lacking several key safety procedures. Train 0600 was travelling at a speed higher that the prescribed speed of 30 km/h which is mandated during	Yes

				method of working was in place were not recorded in the hand over book. As a result, there was a misunderstanding with regards to the destination signal the authorities were given. Poor management and inadequate staffing of the Central Traffic Control (CTC) and control	abnormal working conditions.	

				cabins resulted in weaknesses in the supervision of Traffic Control Officers and deviations to the Standard Operating Procedure.		
9.	Audit on May 2007 train 9484 en route to Naledi Station, collided with the rear of stationary train 9524 at Merafe halt in the Wits		The driver of train 9484 failing to adhere to standard operating practices and passing a series of signals on	Train crew training Metro coaches not within the manufacturer's safety and performance specifications and maintenance cycles	(a) Equipment failures due to: · Deteriorated Trunking Radio Systems, · Degradation of rolling stock maintenance standards, · Non-compatibility/alignment	No

	region. The accident occurred during an overhead traction power failure		danger due to a chronic medical condition which he did not declare to the operator. The train driver concealed the facts that he is diabetic, is receiving insulin treatment and is partially night blind. accident could have been avoided if		between sub-stations and motor coaches. (b) Metrorail Management: · Unclear internal role clarification and associated responsibilities, · Ineffective intra communication between departments and staff · Ineffective implementation of the safety management system as reflected in risk assessments, audits and task observations.	

			Metrorail's Safety Management System had been rigorous and effectively managed		failed brake/slow brake application Limited visibility in train during power failure Cell phones used as backup Poor communication between TCO & Driver	
10.	Train collided with rear end of a stationary train in section First train failed in section due to 3kV power loss linked to PHTE failure & stopped in front of a green				Over-speeding Power failure of OHTE, train lost 3kV power Brakes not immediately applied after loss of 3kV power 2nd train passed signal at danger before collision	No

	signal. 2nd train was behind the 1st train					
11.		Train passed a signal at danger without authority & collided with the rear of a stationary train	Faulty signal, DAL panel had a number of faults before the incident; faults had been occurring days before; TCO struggled to get a hold of driver; only 40% of trunk radios were working; speedometer	TCO gave TD		No

			was faulty on train at shift start			
12.	30 June 2014 at 19h35, Tabak Train Collision	The train was authorized onto a section blocked with a load and collided with a load. The load was left unattended on the mainline and was not declared to track warrant working night shift on the 30th of June 2014.				Yes
13.	02 August 2018 at	Train 5460 was authorized to	There was no Supervision at	Poor protection of the load by the		Yes

	TFR Wonderkop Collision	proceed to Wonderkop's mainline while the line was not clear and it collided with staged load of train 2611.	the CTC and proper handshake between TCO and the driver of train 2611.	TCO and Train Drivers.		
14.	8 April 2011 at Rear end Collision of metro train 9540 into another metro train 9654 near Akasiaboom	The driver of train 9540 in the Akasiaboom incident passed signal AKB 5234 at Amnber and signal WIM5334 that was danger before colliding with the rear end of train 9652 which had stopped at				YesS

		signal WIM 5434 that was danger				
15.	14 January 2011 at Rear end collision of metro train 8884 into another metro train 8882 near alliance.	The driver of train 8884 in the Alliance incident did not drive on sight with his train under control as stipulated by the regulation. The driver of train 8882 in Alliance did not report the failure of the train to the TCO but reported the failed train to the Technician instead. The act of not reporting directly to the TCO				Yes

		when normal train operations are interrupted is a substandard act. Should the correct procedure have been followed the TCO may have had the opportunity to inform the driver of train 8884 of the prevailing circumstances which may have averted the incident				
16.	2 January 2011 at Read end collision of	The driver of train 0907 in the New Era incident				YES

	metro train 0907 into a TFR goods train 4663 near new era.	frequently went above 90km/h during this trip. Brakes were applied at a speed of 93km/h and train 4663 was struck at a speed of 61km/h. The driver of train 0907 did not act correctly on the displayed signal aspect.				
17.	2 February 2009 at 16h12. The collision took place between Springs and	The driver of train 0059 passed signal BGS 653 T at danger.	Train drivers of metro are required to observe a large number of signals	The driver was not wearing his glasses.		No

	Brakpan. A track circuit fault was reported. The signal was therefore displaying red and the train (0057) stopped at a signal (BGS 655T). At about 17h15, train (0059) collided with a rear of train 0057.		during the course of their shift. A large proportion of this takes place on multi and double lines sections where the identification of the correct signal is not always easy. These drivers do not have co drivers or assistant drivers with the neither are they assisted			

			with technical equipment to prevent or warn of the passing of a signal danger.			
18.	19 May 2011 at 17h52 The collision occurred between Mzimhlophe and Phomolong. Soweto train 9432 enroute from Johannesburg to Naledi	The train driver was driving above the speed limit.	Driver failed to stop the train before colling with a broken-down train.	Faulty train in a section.		No

	collided against train 9482 which was stationary in the section after having fault.					
19.	Two (2) TFR trains no. 1282 and 1494 collided near Kalbaskraal station in the Western Cape. The collision occurred near the manually operated points	Miscommunication between the train assistant and the dolomite train driver.	Both train drivers acting on the same authority given by the train assistant.	High risk area, no procedure for push back in the triangle	Instruction not repeated by the driver who acted on the authority not meant for his train	No

	just outside Kalbaskraal station.					
20.	PRASA train no;1865 collided with a TLB on the Elandsfontein line towards Kempton Park	the trenching work was conducted to close to the railway line	failure by management to enforce compliance to safety procedures, systems and standards when contractors are working; contractors to submit a risk assessment prior to	YQ was not issued to the driver, contractor was not supervised and did not report to the CTC that they were working on the day		No

			commencing with work			
21.	On the 20th of February 2017 at 18h08, PRASA Train 9478 travelling from De Wildt to Rosslyn Station collided head-on with another PRASA Train 9457 travelling from Pretoria to De Wildt Station.	Train 9457 was erroneously authorised onto an occupied line. The panel hand over process between TCO's which was accompanied by an instruction to authorise Train 9457 was done improperly and contrary to Train Working Rules	The signalling system had not been functional for a protracted period due to theft and vandalism, and this led to prolonged abnormal working requiring the authorisation of trains between De Wildt and	Train working rules not followed properly (absolute working)	The system of operating is not carried out in accordance with the Train Working Rules and the General Operating Instruction which provides that "When, for any reason, signals or points are not to be operated, the train control officer must place (a) magnetic reminder cap(s) over the interlocking area, signal or points push	Yes

			Rosslyn Stations.		button(s) on the control panel/console".	
22.	Collision between the light train locomotive 34821 and the last wagon of the TFR train 8499 that was standing fouling the railway line with one and half wagon from the clearance mark at Musina Yard	the train 8499 was left standing foul on line one	Lack of management enforcing the general appendix and training working rules to train personnel	Train personnel not familiar with the yard layout	The train working rules were not adhered to by both TFR and PRASA crew	

	on the 12th of October 2014					
23.	Train Collision between Trains 4103 and 7208 at Pyramid South on the 13th od May 2017	The immediate cause identified was found to be the TCO did not know the exact position of the failed locomotives as this was never recorded and therefore the train driver did not know where the failed locomotives were in the section. Due to this, the train driver did not expect to see the	The root cause identified was found to be the lack of supervision in the CTC. Due to a shortage of personnel, the coordinator was required to work as a TCO and therefore there was no supervisor to ensure that the TCOs were performing	The train driver repeated the authority back to the TCO without querying about the specific location of the standing locos. The train driver did not see the locos positioned around the curve due to the vegetation in the area. There was a shortage of personnel in the		No

		locomotives standing around the curve and was not able to stop the train in time to prevent the collision.	their work according to the TWRs	CTC resulting in the coordinator performing TCO duties.		
24.	At Denver Station train no. 1602 (business express) collided with train no. 0600 (metro plus express) in the rear end on the 28th of April 2015	Human error signal passed at danger	Train 1602 passed the signal DN2 at danger. Train driver of 1602 didn't adhere to the speed limit of the section of 70Km/h the train was	Lack of substance abuse testing when starting duty, confirming fitness for duty.	Communication was down at George Goch CTC due to power failure and the CTC was inaccessible for the driver of train 0600 to confirm the signal aspect	No

			travelling at 90km/h			
25.	Train number 9013 collided with the rear of train 9019 in the section between Lenz and Midway, in the vicinity of mast polesDB41/736 and DB41/791. On the 2nd of February 2009	The immediate cause of the collision is the failure of a signalling module that transmitted a condition that the track was not occupied when train 9019 was in fact occupying the track. This condition allowed train 9013 to enter the section. On entering the section, the driver	The root cause of the collision is the failure of the process for coordinating the activities of the TCO and the technician doing maintenance on the line. The process for testing and handover of signalling equipment was not followed,	There was a failure of communication due to inadequate communication infrastructure.	No handover of the section to the TCO by the technician. However, the TCO resumed operating the signals while the technician was still repairing. driver of train 9013 was not aware of the signalling aspects ahead of his train and as a result didn't react appropriately to signal aspects that were presented to	Yes

		of train 9013 failed to react appropriately to a signal that fell back to danger in front of him.	and thus trains were allowed to run on signals before the signalling system was verified fit for service.		him. He passed signal 6742 at danger.	
26.	On 8 Mayv2009 at 17:07Metro train 9543collided with the rear of train 9549in the platform at Wonderboom station. Train 9549 started	Train 9543 disregarded the permanent speed restriction on the line. Train 9543 passed signal PNL 2264 without slowing down, thereby disregarding Metro	Train drivers of Metro trains are required to observe a large number of signals during the course of their shift. A large proportion of this takes	Rear train protection was not carried out in accordance with Metrorail General Operating Rules.	train drivers of Metro trains are required to observe a large number of signals during the course of their shift. A large proportion of this takes place on multi line and double line sections where the identification of the correct signal is	No

	moving from the platform just seconds before the accident occurred, which mitigated the effects of the accident.	General Operating Instructions.	place on multi line and double line sections where the identification of the correct signal is not always easy. These drivers do not have co-drivers or assistant drivers with them. Neither are they assisted with technical equipment to prevent, or		not always easy. These drivers do not have co-drivers or assistant drivers with them. Neither are they assisted with technical equipment to prevent, or warn, of the passing of a signal at danger.	

			warn, of the passing of a signal at danger.			
27.	On the afternoon of 17 July 2015 at about 17h54, Train 9404 collided with the rear-end of Train 9934 which had stopped at signal CRN69 which was at danger. The incident occurred in the	The collision was as a result of signal BOY 80 incorrectly displaying a yellow aspect for Train 9404 to proceed (as result of faulty wiring in apparatus case A1051) onto a track occupied by Train 9934.	Lack of spares and/or resource constraints to properly repair equipment; Shortages in staff complement; raining of personnel: The technician did not adhere to accepted and required	The view of the Driver of Train 9404 was obstructed by the overgrown vegetation on the side of the rail. He was thus prevented from seeing train 9934 which was stationed after the curve between signal BOY 80 and CRN 69. The	The system indicator of critical information about train movements is faulty since the displayed light is not reflecting actual track information. In this regard, the yellow light indicator for signal 80 on the up slow line on the unit displaying signal 80 and 81 switches was not working on the day of the incident and, at the	N

	section between Booysens and Crown Stations. The incident took place between signal BY80 and CRN69 after mast pole 16/882		procedures when attending to a fault (checking, testing after re-pairs, reporting back, etc.). No refresher training is provided to TCOs on the system that they use daily to perform their duties.; Lack of supervision of signal personnel and TCOs by	overgrown vegetation on the curve obstructed the Driver's view of Train 9934 before signal BOY 80, which would have afforded him enough time to stop the train.	time of the interview, was still not working. This means that if there is no train in that section, the light does not give an indication, leaving the TCOs to assume that the blank light is actually indicating yellow	

			Supervisors / Managers			

ANNEXURE 2: Questionnaire

The Link between Abnormal Working and Collisions Questionnaire

Thank you for agreeing to participate in this research study on the link between abnormal working and collisions. The study seeks to assess if abnormal working can be associated with increases in the likelihood of collisions. It is believed that the establishment of an association between collisions and abnormal working may lead to the identification of additional safety gaps that can be closed to minimise the likelihood of collisions occurring.

This research topic was established because collisions impinge on the safety of railway passengers and employees, resulting often in injuries and fatalities in some instances. It is imperative that a more comprehensive understanding of these instances is pursued. Railway Safety Regulator oversees the safety of South Africa's vast and complex railway network. It is South Africa's Regulatory body interested in promoting safe railway operations through appropriate support, monitoring and enforcement, guided by an enabling regulatory framework. Collisions between rolling stock and objects have historically contributed more than 90% of the total collisions reported during the past three financial years as opposed to collisions between rolling stock on a running line, which have contributed less than 2% of the total collisions. Most collisions are reported by Transnet Freight Rail and Passenger Rail Agency of South Africa, with Transnet Freight Rail reporting a higher number of collisions.

As the data collected by the Railway Safety Regulator has indicated, the number of collisions reported annually remains high; the high instances of collisions recorded is both significant and concerning. It is therefore pertinent to study and understand the factors that contribute to collisions within the South African railway industry. One of those factors that may contribute to collisions may be abnormal working.

You will be asked to respond to the questionnaire that follows. Please respond honestly. Please respond to each question included. The questionnaire is preceded by a few personal non-identifying questions. Your identity will remain anonymous.

Job Title:	
Organisation:	
Gender:	
Age:	
Duration in current post:	

Indicate the extend to which you agree with the following statements:

No.	Questions	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1.	My supervisor is always available during abnormal working.					
2.	I feel that I work harder when performing manual authorizations than when I can use the VDU.					
3.	I need to concentrate more when I am performing manual authorizations.					
4.	I can take rest breaks as frequently as I need them when I am performing manual authorizations.					
5.	Performing manual authorizations is stressful.					
6.	I often perform manual authorizations.					
7.	There is a lot of pressure when performing manual authorizations.					
8.	I can manage my work well when performing manual authorizations.					
9.	The implementation of emergency working in the section has improved the working conditions of issuing manual train authorisation.					
10.	Near miss incidents in my line of work are recorded and noted.					
11.	I attend training and refresher training when it is required.					
12.	My supervisor discusses circulars with me.					

The following questions require you to give your opinion. Please answer all the questions below. Space is provided for you to elaborate if you need to.

13. How does the telecommunication system used affect the manual train authorization process (Trunk radio system only allows 4min calls and calls cut off when the 4min time has been reached)?

14. On average, how many manual train authorizations do you issue per day?

15. How often is your work supervised (signing of the train registers by the Supervisors/Section Managers)?