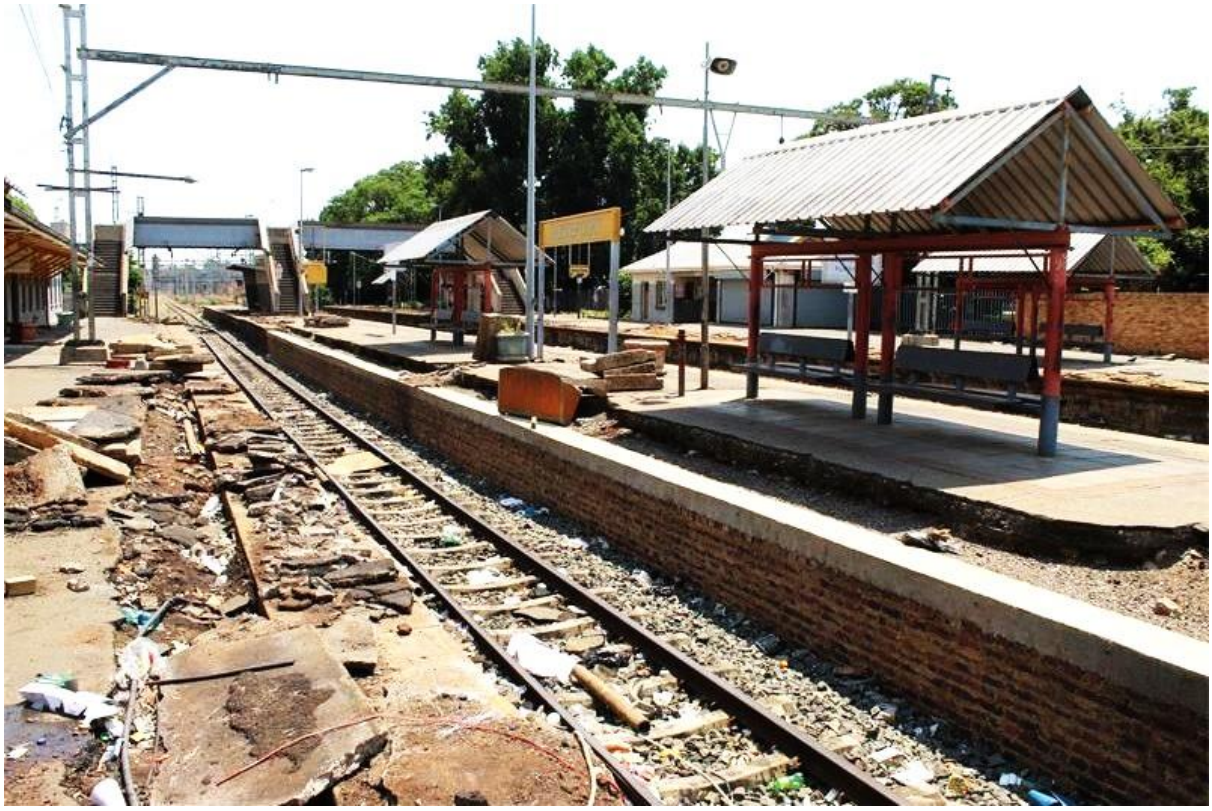
RAILWAY SAFETY REGULATOR

RAIL SAFETY ON THE RIGHT TRACK

An Investigation into the Impact of Theft and Vandalism on Train Operations

FINAL REPORT



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EXECUTIVE SUMMARY

The South African railways are constantly under risk from theft and vandalism. In fact, the South African railway system frequently experiences theft and vandalism. This is partly because there is a lot of trespassing on the mainly unfenced railway network. Graffiti, vandalism, and theft from rolling stock or line-side equipment are just a few of the criminally motivated reasons for rail trespassing. The other reason is due to inadequate security of railway assets.

The high number of theft and vandalism incidents that have been reported is significant and alarming because these occurrences can impair the operational safety and effectiveness of trains. It is therefore crucial to investigate and evaluate how theft and vandalism affect train operations.

The data collection approach for this research project employed a combination of both qualitative and quantitative data collection methods. The quantitative data collection procedure included the collection and analysis of various documents provided by railway operators and the analysis of theft and vandalism incidents. The qualitative data collection approach included conducting interviews with relevant PRASA and TFR personnel to gather their insights on their experiences with the effects of theft and vandalism.

According to the study's findings, theft and vandalism frequently have an impact on service delivery, organisational management, and the safety management. It was reported that more instances of equipment theft and vandalism had resulted in section failures and unreliable train operations, leaving the passenger network in an unacceptable state. The findings of this research paper align with this assertion. It appears that indeed, theft and vandalism often resulted in a negative impact on operational safety. In addition to the safety implications, the direct implications were on Train Operations; the theft and vandalism challenges recorded in the infrastructure departments often directly limited the ability of Train Operations to operate trains.

1. INTRODUCTION

Theft and vandalism are common occurrences within the South African railway system. The level of theft and vandalism recorded is believed to be compounded by the largely unfenced railway network which experiences a considerable amount of trespassing. Theft from rolling stock or line-side equipment, vandalism, and graffiti are only a few examples of the criminally driven motives for railway trespassing. The Railway Safety Regulator noted in the 2020/21 State of Safety report that the extent of theft and vandalism significantly increased during the 2020 COVID-19 defence response lockdown: a record levels of theft and vandalism of railway components such as railway lines, signalling components and overhead traction equipment was logged during this period. The 2021/22 State of Safety report showed that 97% of theft and vandalism instances had a substantial negative impact on train operations; incidences of theft and vandalism are believed to be contributory factors to the high amount of manual train authorisations recorded at both Transnet Freight Rail and the Passenger Rail Agency of South Africa. While instances of theft and vandalism fall within the categorisation of security-related incidents, they are monitored by the RSR since safety and security concerns are interconnected. The RSR reported that the theft of assets contributed a total of 80% to the overall security-related incidents recorded during the 2021/22 reporting period.

The high instances of theft and vandalism incidents recorded is both significant and concerning as these incidents can lead to the degradation of operational safety and efficiency of trains. It is therefore pertinent to investigate and quantify the impact of theft and vandalism on train operations.

2. PURPOSE OF THE RESEARCH STUDY

This research project will set out to quantify the impact of theft and vandalism on train operations, highlighting the effects of theft and vandalism on the different train operational departments.

Incidents of theft and vandalism are recorded under the security-related incidents namely, categories 1 and 2 in the Annual State of Safety Report. The Annual State of Safety reports have noted that theft and malicious damage (vandalism) of assets has an impact on operational safety. The affected operational sectors are as follows:

a) Rolling stock components in sections,
b) Rolling stock components in yards and sidings,
c) Civil infrastructure components in sections,
d) Civil infrastructure components in yards and sidings,
e) Overhead traction equipment in sections,
f) Overhead traction equipment in yards and sidings,
g) Train authorisation and control systems and equipment in sections,
h) Train authorisation and control systems and equipment in yards and sidings,
i) Ancillary equipment, including public address (PA) systems, information boards and closed- circuit television (CCTV).

This study will focus on the above operational sectors as outlined under categories 1 and 2. The aim will be to produce accurate information regarding how the instances of theft and vandalism contribute to challenges experienced on train operations. The study will analyse instances of theft and vandalism that occurred between 2018 and 2022. The research project will attempt to use the findings of the impact of theft and vandalism on train operations to suggest proactive recovery implementation processes to reduce the negative effects of theft and vandalism on train operations.

3. LITERATURE REVIEW

The rail network is one of the most crucial infrastructure components in most economies all over the world (Wilson & Norris, 2006). Rail is charged with transporting both people and freight across vast distances as effectively as possible in various countries, ensuring that there is not total gridlock on the roads during commute hours (Wilson & Norris, 2006). Essentially, a well-developed rail infrastructure is vital from a strategic point of view as it offers a low-cost, high-efficiency way to expand the transportation capacity (George, Mokoena & Rust, 2018). As a result, maintaining the condition of the rail network must be a top priority for railway operators, the general public, and relevant stakeholders (George *et al*., 2018).

Railway transport is a large complex sociotechnical and safety-critical system (Read, Naweed & Salmon, 2019). As a sociotechnical system, rail is complex in structure, functions, operations, management, and other aspects and experiences catastrophic risks and events (Liu, Zhang, Yin & Li, 2021; Read *et al*., 2019). This is because large sociotechnical systems are interaction-dominated and complex (Kyriakidis, Kant, Amir, & Dang, 2018) and railway undertakings' Safety Management Systems (SMSs) are predicated on a system-based approach that emphasises the interaction and interdependence of internal and external elements that influence the operational process (Georgiev, 2014). High operational safety should therefore be ensured by a well-structured and properly operating SMS (Georgiev, 2014). However, at times, due to numerous factors, the SMS of a railway undertaking may fail leading to the emergence of a crisis of safety management (Georgiev, 2014).

The Complexity of Railway Safety Management Systems

A safety management system (SMS) is understood to refer to either a management system specifically aimed at safety or a system that is used to manage and control safety (Li & Guldenmund, 2018). An SMS is the intersection of three perspectives, namely, safety, management and system (Li & Guldenmund, 2018). The development of each of these three components independently determines how an SMS changes over time to some extent (Li & Guldenmund, 2018). The focus of safety is on the prevention of its opposite; that is, safety focuses on risk (risk reduction specifically) —accidents, damage, or injuries, which are frequently represented with models and metaphors (Li & Guldenmund, 2018). Both the phrases management and system have extensive definitions: input-process-output is the fundamental tenet of a system, while management includes planning, organising, directing, and controlling

activities (Li & Guldenmund, 2018). System safety is primarily concerned with engineering reliability (Li & Guldenmund, 2018). System safety helps decrease failures of components and systems of machines and installations, reinforcing safety hardware systems (Li & Guldenmund, 2018).

An SMS is commonly defined as the management procedures, elements and activities that aim to improve the safety performance of and within an organisation (Li & Guldenmund, 2018). A company's definition of safety is the absence of accidents in its projects, plants, and manufacturing facilities. The primary objective of safety management is thus usually to prevent accidents because these not only result in financial loss but also harm to reputation (Li & Guldenmund, 2018).

In organisational management, a safety goal (such as zero accidents) is far more definitive than any risk acceptance levels; zero accidents simply means no accidents (Li & Guldenmund, 2018). Safety defences, which comprise safety equipment, devices, and various behavioural activities, are employed to prevent accidents in order to accomplish this straightforward goal (Li & Guldenmund, 2018). Safety equipment or devices are the hardware defences that prevent or protect against any harm (Li & Guldenmund, 2018). Many accidents happen not because they cannot be averted, but because the organisation failed to recognise the weaknesses in their safety systems and failed to learn from or retain the lessons from earlier internal or external incidents (Anca, 2007). Sometimes, these weaknesses are revealed when the implemented safety equipment and devices fail. This is frequently the case since safety equipment and devices are set up as complete mechanical safeguards designed to prevent accidents (Li & Guldenmund, 2018). Within the railway environment, these safety equipment and devices (set up as complete mechanical safeguards) are usually the primary rail infrastructure components. It is when these mechanical safeguards fail that the likelihood of experiencing catastrophic risks and events arises.

However, rail as a complex sociotechnical system has numerous interconnected parts that interact on a variety of spatial and temporal domains, and the interactions among the parts take precedence (Kyriakidi et al., 2018). As a result, the identification of causes is often complicated (Kyriakidi et al., 2018).

The South African Railway Context

In South Africa, rail network comprises two primary units; the freight rail network occupied by Transnet Freight Rail (TFR) and the passenger rail network occupied by Passenger Rail Agency of South Africa (PRASA) and Bombela Operating Company (BOC) (George et al., 2018).

Railway infrastructure is made up of track structures, assets for train authorisation, overhead traction equipment, culverts, bridges, and telecommunications equipment (Ramuhulu & Chiranga, 2018). That means that the primary rail infrastructure components in rail include formation, railway structures, signalling, telecommunications, permanent way, and electrical systems (George et al., 2018). The railway maintenance depot is required to provide a railway infrastructure that is always available so that train operators can operate trains safely (Ramuhulu & Chiranga, 2018). Fiumara (2015) describes “critical infrastructure” as a system, a resource, a process, or a set, whose destruction, interruption, or temporary unavailability, has the effect of significantly affecting the efficiency and the regular operation of a Country. The critical infrastructure’s destruction also has the potential to affect the security, the economic and the social system, including central and local public administration institutions (Fiumara, 2015). Most of the critical infrastructure in the railways has been affected by security incidents (Fiumara, 2015); these incidents can be vandalism of equipment linked to railway traffic, the intrusion of unauthorised individuals who temper with signal equipment, etc.

George et al. (2018) found that the key factors contributing to the condition of the current railway infrastructure were the management of the primary railway infrastructure components as well as factors such as theft and vandalism of railway assets, number of train derailments, collisions, and fires. Essentially, the management of the mechanical safeguards and the presence of occurrences, had an impact on the state of said mechanical safeguards. In their paper evaluating the state of the public freight and passenger rail networks in South Africa, George, Mokoena and Rust (2018) found that the increasing trend of theft and vandalism of rail infrastructure equipment was one of the primary contributors to section failures and unreliable train operations, chiefly along the general freight lines. George et al. (2018) found that the high instances of theft and vandalism left certain sections along the general freight network in an unacceptable condition (George et al., 2018). Ramuhulu and Chiranga found and reported on similar findings; they found that theft and vandalism was among the major causes of railway infrastructure failures in the TFR business unit (Ramuhulu & Chiranga, 2018). Other factors like poor railway infrastructure maintenance, ageing railway infrastructure, vegetation, extreme weather conditions, the failures of other Transnet departments, and a lack of maintenance contributed to the noted railway infrastructure failures (Ramuhulu & Chiranga, 2018).

More instances of equipment theft and vandalism have resulted in section failures and unreliable train operations, which have left the passenger network in an unacceptable state (George et al., 2018). These difficulties have been exacerbated by recurrent train burnings, demonstrations against the delivery of community services, flooding, substation failures, and sinkholes on crucial stretches of the network (George et al., 2018). This creates a highly hazardous environment as unreliable railway infrastructure can result in rail-related incidents that increase the South African railway operators operating costs and increase the risk of casualties and environmental harm (Ramuhulu & Chiranga, 2018). Ramuhulu & Chiranga (2018) reported that the TFR Business Unit had lost a sizable sum of money, experienced the death of several personnel, and paid out on several civil claims due to the failures on its railway infrastructure. PRASA, in particular, is facing the challenge of theft and vandalism in part due to the having an open rail system, leaving it susceptible to access control challenges as well as theft and vandalism (George et al., 2018).

The Theft and Vandalism Problem

It was reported by Ramuhulu & Chiranga (2018) that South Africa loses more than R5 billion a year because of copper cable theft. The copper cable, for instance, is used to conduct electricity in the TFR Business Unit's electrical and substation infrastructure (Ramuhulu & Chiranga, 2018). Given the size of the infrastructure network, it is challenging for the Transnet Business Unit to patrol the entire network (Ramuhulu & Chiranga, 2018). The theft of copper is a significant challenge within the South African railway environment. Copper as the best conductor of electricity is widely used in the rail industry as well as in the telecommunications systems (Fiumara, 2015). This has led to a worldwide demand for copper (Fiumara, 2015). Fiumara (2015) elaborated further and pointed out that there was high demand for copper; the demand for copper as a raw material currently exceeds its production. This has caused a rise in its stock price, which has tripled in the last decade, subsequently multiplying the theft incidents (Fiumara, 2015). Additionally, the primary targets are signalling cables, telecommunication cables, electric substations, overhead power lines, signalling boxes (known as live equipment) and metal non-live equipment such as metal fences that are sold for scrap (Lund, Tedesco & Bigi, 2015).

The ability of infrastructure maintenance departments to focus on maintenance is hampered by theft and vandalism, which also compromises performance, safety, availability, and reliability (Ramuhulu & Chiranga, 2018). Companies and departments are losing personnel and assets as a result of theft and vandalism-related failures, which cost millions (Ramuhulu & Chiranga, 2018).

Ramuhulu & Chiranga (2018) conducted surveys with railway personnel in their study to capture the factors affecting railway infrastructure negatively. In their findings, it was highlighted that signalling theft-related failures were extremely high. The TFR Business Unit thus spent a significant amount of time attending to theft-related signalling failures which increases the operational budget and affects the day-to-day running of the business unit. Signalling refers to train authorisation system components including track circuits, axle counters, signals, cables, remote control, interlocking, standby power supply, Condition Assessment Systems, and switches/points. Providing a reliable and safe train authorisation system is the primary objective of the railway authorisation system, and a defective train authorisation can lead to accidents that can result in fatalities and environmental disaster.

The Telecommunications subsection includes telecommunication infrastructure such as fibre optic cables, tele-control, Walkie-talkies, site links, telemeters, etc. Some of the TFR Business Unit's communication devices used for radio communication were installed in the mountains, and thus vulnerable to theft and vandalism. One of the primary causes of telecommunication failures was reported by Ramuhulu & Chiranga (2018) to be theft and vandalism. According to the Ramuhulu & Chiranga survey, theft and vandalism was among the key reasons and main causes of permanent way (perway) infrastructure failures. Perway was highlighted as including basic component such as rails, rail fastenings, ballast, sleepers, and turnouts. Theft and vandalism were among the causes of electrical infrastructure failure. Companies like Eskom, Telkom, PRASA, and other communication corporations that use copper to either conduct energy or transfer information were highlighted as also being impacted by copper cable theft (Ramuhulu & Chiranga, 2018). The electrical infrastructure is part of the Overhead Traction Equipment (OHTE) department or components. The OHTE includes the catenary wire which has a structural function to suspend the contact wire through droppers and an electrical function to conduct traction and fault currents. The contact wire provides the electrical live interface with the locomotive for traction purpose (Ramuhulu & Chiranga, 2018). From the research articles, it appears that theft and vandalism usually affect numerous critical railway infrastructure, increasing risks.

Theft and Vandalism Risk Management

All organisations require a security system that will ensure the protection and integrity of information, assets, and the core business (Fiumara, 2015). To prevent and eliminate failures due to theft, railway operators need to make greater investments in asset security. Risk management to address theft and vandalism will require the enhancement of asset protection,

security controls, and security measures (Ramuhulu & Chiranga, 2018). This can be achieved by putting in place efficient security measures, such as sending more security officers to monitor the railway infrastructure, and installing high-tech security surveillance cameras (Ramuhulu & Chiranga, 2018).

4. METHODOLOGY

The data collection approach for this research project employed a combination of qualitative and quantitative data collection methods.

Quantitative data collection

The quantitative data collection procedure used included the collection and analysis of security data submitted by PRASA and TFR to the RSR to quantify the theft and vandalism rates reported in the past. This approach saw the data collected summarised and represented graphically. The second quantitative data method used included analysing several types of documentation submitted to the RSR by PRASA and TFR; this information included various security reports, condition assessment reports, vacancy rates, risk assessments, incident data, rostering plans, etc. related to security incidents that fall within categories 1 and 2 as reported in the Annual State of Safety Report (ASOSR) between 2018 and 2022. This data was analysed to gather the impact of theft and vandalism incidents on train operations.

The researchers also used other documents related to theft and vandalism that were submitted for Technology Reviews and the Safety Permit Conformity Assessment Method. The information collected from these documents was used to construct an explanatory case study. The case study focused on the request submitted by PRASA to reinstate the train service between Pienaarspoort and Pretoria under 3KV DC using electric multiple units (EMUs). The documents reviewed during the course of this research are included in Annexure A.

The analysis of security data for categories 1 and 2 submitted by PRASA and TFR to the RSR was analysed and presented.

Qualitative data collection

The qualitative data collection approach included conducting interviews with relevant PRASA and TFR personnel to gather their insights on their experiences with the effects of theft and vandalism. The data collection approach was aimed at gathering data around the potential impact of theft and vandalism on operational safety and identifying the departments involved.

The researchers developed the interview questions that were used in this study. The questions are attached at the end of the report in Annexure B. The researchers also held informal discussions with TFR and PRASA personnel; during these informal discussions, they enquired about the processes around managing theft and vandalism. The results section that follows will include some of the insight shared during these informal discussions and the findings from the interviews conducted.

5. RESULTS

The results presented in this document are focused on analysis of theft and vandalism cases. As previously stated in earlier chapters, the incidents of theft and vandalism are recorded under the security-related incidents namely, categories 1 and 2. These two categories are further broken down into the affected operational sectors. These sectors are broken down further as follows for both category 1 (theft) and category 2 (vandalism):

a. Rolling stock components in sections,
b. Rolling stock components in yards and sidings,
c. Civil infrastructure components in sections,
d. Civil infrastructure components in yards and sidings,
e. Overhead traction equipment in sections,
f. Overhead traction equipment in yards and sidings,
g. Train authorisation and control systems and equipment in sections,
h. Train authorisation and control systems and equipment in yards and sidings,
i. Auxiliary equipment, including PA systems, information boards and CCTV.

To aid in the ease of reference of the affected sectors outlined above, each sector was further categorised by the infrastructure department it fell into. Table 1 below includes the further categorisation.

Table 1: Infrastructure department categorisation

Category	Railway Infrastructure Department
1-a and 2-a	Rolling Stock
1-b and 2-b	Rolling Stock
1-c and 2-c	Perway
1-d and 2-d	Perway
1-e and 2-e	Electrical
1-f and 2-f	Electrical
1-g and 2-g	Signals & Telecoms
1-h and 2-h	Signals & Telecoms
1-i and 2-i	Stations

The table groups the assets affected in the sections, in the yards and sidings together under one department. Categories 1-h, 1-g, 2-g and 2-h are grouped within both the Signals and Telecoms departments as they often included assets from both departments.

Analysis of Assets Stolen and Vandalised

Table 2 below includes examples of the assets that were frequently vandalised and stolen from the data analysed. The information on which assets are usually stolen was gathered from both the interviews with the PRASA and TFR personnel as well as the theft and vandalism incident data analysed.

Table 2: Assets Stolen & Vandalised by Department

Department	Vandalised	Stolen
Signals	Track Side Equipment (Small Cables, Copper Equipment, etc), Points Machine, Cables, Signal Wires, Trackside Box, Signals Poles, Point Machine Wirings, Signal Bulb, Excel Counter Head, Mast Pole, Shunt Signal, Apparatus Case	Cables, Track Boxes, Power Supply, Track Relay, Core Cable, Signal Head Cables
Perway	Palisade Fence, Grease Pot	Pendrol Spring, Rail Clips, Components
Telecoms	Public Info Systems, Display Boards, Optic Fibre Cables	Trunk Radios In Footplate, Telemeter, Optic Fibre Cable
Rolling stock	Windows, Plain Trailers, Cab Door Locks, Panel Boxes, Lights, Train Cables, Observation Window, Track Switch	Cab Door Locks, Copper Pipes on Metro Trains, Roof Panel Cables on Metro Trains, Vacuum Gauge, Panel Box Cables on Metro Train, Power Car Batteries, Train Jumper Cable
Electrical	Negative Return Cable, Electrical Cable, Overhead Catenary Wire, Contact Wire, Power Supply Cable, Isolated Switches, Overhead Wire, Droppers Cables	Overhead Cable, Catenary Wire, Busbar, LT Cable, Earth Cables
Stations	Speed gate, CCTV Camera, Announcement Speakers Poles, Train Schedule Board Pole, Lights, Ceiling, Ticket Office, Door Handles, Camera Box	CCTV Cameras, Stop Board Sign, Speakers

When the collected data was analysed for examples of property often vandalised and stolen from the railway operators, it became apparent that a lot of the assets targeted were cables. The interviews highlighted that the cables were usually cut (and taken). The feeder positive cables and copper bass bars cables were often targeted at the substations while the catenary wires and contact wires are often targeted at the sections. The operators' interviews indicated that the target seemed to be cables with copper. According to the interviews the cables with aluminium were hardly targeted. The other assets targeted included train windows and doors, apparatus case, points machines, points leads made from steel, and equipment in the relay room.

Theft Occurrence Analysis

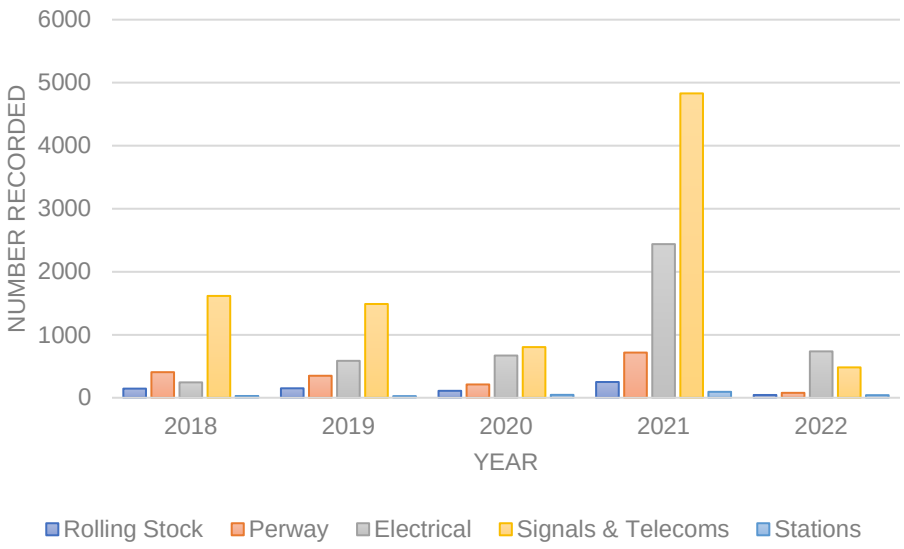

Figure 1: Theft incidents recorded in the Section

Figure 1 indicates that Signals and Telecoms as well as Electrical equipment and components had the highest number of in-section theft incidents in 2019, 2020, and 2021. It appears that these are the commonly stolen assets. The highest instances of theft were recorded in 2021 across all departments. The graph shows an increasing trend on number of electrical components stolen from 2018 to 2021.

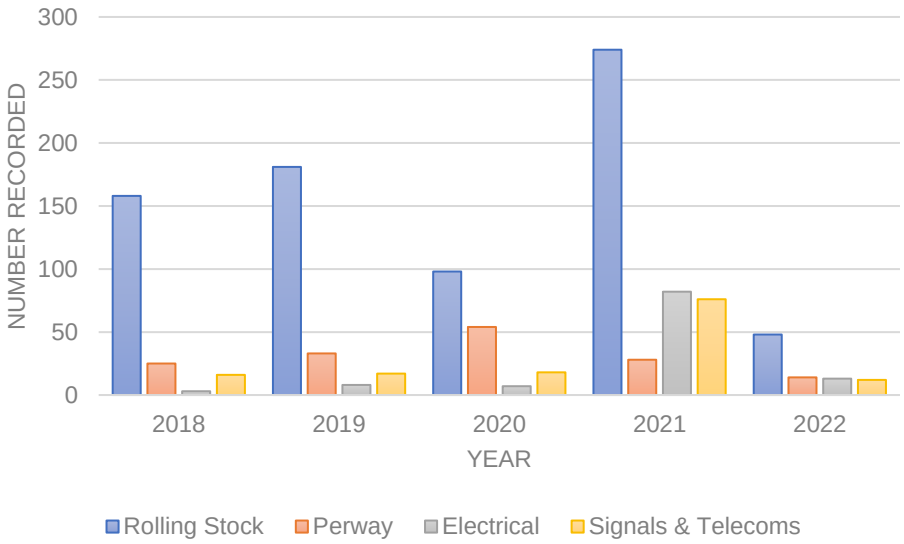

Figure 2: Theft incidents recorded in the Yards & Sidings

Figure 2 indicated that there were comparatively fewer incidents of theft recorded in the yards than in the sections. Yard incidents indicate more Rolling Stock assets were stolen, however, the

appearance of an increase in Rolling Stock theft in the yards and sidings is deceptive in comparison to the data from the sections. This is because the number of Rolling Stock assets stolen remains relatively constant, the noticeable difference in the number of assets stolen per department is because there are significantly less Perway, Electrical, Signals and Telecoms assets stolen in the yards and sidings.

Vandalism Occurrence Analysis

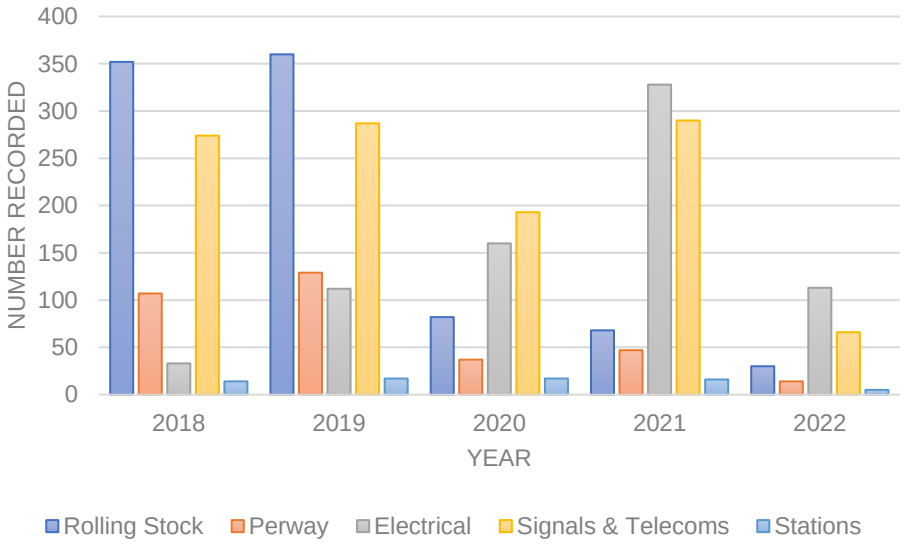

Figure 3: Vandalism incidents recorded in the Section

Figure 3 shows that more Rolling Stock, Signals and Telecoms assets were vandalised between 2018 and 2019. The incidents of assets vandalised at Stations were the lowest. Signals and Telecoms assets were the most vandalised in total across the years under analysis. The number of instances of vandalism of Electrical assets was on a steady increase from 2018 to 2021. In 2022, the number of Electrical assets vandalised year to date dropped to 113, from 328 the previous year.

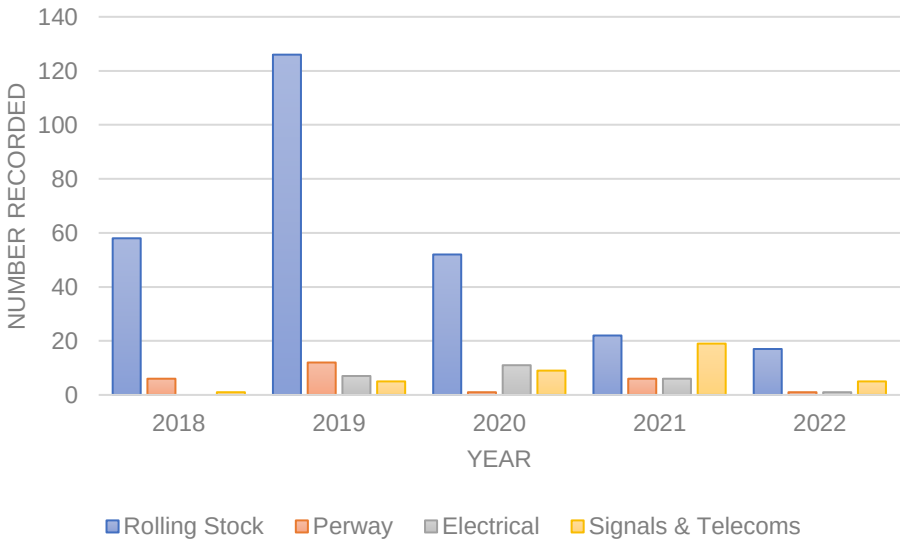

Figure 4: Vandalism incidents recorded in the Yards & Sidings

The highest number of assets vandalised in the yards and sidings were from the Rolling Stock department. A moderate number of Signals and Telecoms assets were vandalised in the yard. The departments with the least number of incidents recorded in the yards and sidings were the Electrical and Perway departments.

The Pienaarspoort to Pretoria Line Case Study

PRASA submitted a request for the reinstatement of train service between Pienaarspoort and Pretoria under 3KV DC using EMUs. PRASA was required to submit documents in support of this request as per the submittal review process. PRASA submitted several documents, some of which are captured in Annexure A. Among the documents submitted was evidence of how theft and vandalism had affected PRASA's ability to reopen the line. The following documents containing details of the effect of theft and vandalism were of interest:

- Pienaarspoort – Pretoria Corridor Condition Assessment Report for the deployment of EMU
- Perway Risk Assessment Gauteng North
- Telecoms Pretoria to Pienaarspoort Risk Assessment
- Telecoms Readiness and Condition Assessment Report Pretoria to Pienaarspoort Line
- Service Resumption Risk Assessment

The condition assessment report showed the current condition of the signaling system from Pretoria to Pienaarspoort. The report highlighted that the corridor experienced a spate in vandalism and theft after it was re-signaled. These instances of theft and vandalism had devastated the working of some of the signaling elements as the signaling was vandalised to an extent of destruction. The damage to the signaling equipment was not limited to the Pretoria to Pienaarspoort only. The other lines affected included the Saulsville to Pretoria, Hercules to Pretoria, Lenz to Johannesburg, Naledi to Johannesburg, Leralla to Johannesburg, and Pretoria to Kaalfontein lines. The damage resulted in these lines being operated under a degraded mode.

The Pretoria, Rissik, Koedoespoort, Watloo, Eerstefabrieke, Greenview, and Pienaarspoort stations within the Pretoria to Pienaarspoort corridor were affected. The report outlined how the vandalism targeted junction boxes and main cables, the Signal equipment room, the signal cables, the points and axle counters. The impact left signals without power due to the theft of main cables. Axle counters and points were often left damaged and in need of repairs. The damage of the signaling system in that corridor left only 2 of the 6 stations operational. As a result, the Infra Engineering Services was forced to engage in a Signals Rehabilitation project costing R 20 million running over a 2-year period. This project was aimed at addressing the challenges of defective elements to improve signal equipment availability and bring it to its optimal level. The continued risk of theft and vandalism required the deployment of additional security. It was also necessary to initiate a maintenance plan of the signals including planned routine maintenance and scheduled preventative maintenance activities.

The theft and vandalism of signal equipment caused train delays and cancellations. The trains had to be manually authorised in accordance with PRASA's Train Working Rules (TWR). The trains also had to travel at lower speeds with the Train Control Officers (TCOs) having to ensure that the train drivers on duty did not exceed the newly implemented speed restriction.

The Service Resumption, Telecoms and Perway Risk Assessments showed the presence of the following risks related to theft and vandalism in the different departments:
Telecoms:

- Public address systems needed to be rehabilitated
- Some voice recording systems were not functional resulting in an absence of voice recording for train authorisations and data recording for train movement. The TCOs were forced to use non- recording phones

to communicate critical information to the train personnel and depots as they could not rely on Trunk radio systems.

- TCO's at Pretoria North CTC had to utilise a landline handset/cellphone when giving authorities and communicating in line with the running of trains.
- The Optic fibre network transmission was experiencing service delays resulting in the absence of communication on Tele control and telephones.
- Operational panel blackouts related to the limited functionality of the optical transmission network meant that TCOs could not view trains movement, leading to the Implementation of abnormal working.

  Impact on Train Operations: Deviations from TWR and planned working such as TCOs using non-recording phones to relay critical information, implementation of speed restrictions, additional tasks allocated to TCOs, and inability to view train movement on the display units.

Perway:

- The theft and vandalism of major Perway components such as Rail Clips or Fastenings, Sleepers and Rails was affecting Infrastructure readiness.
- Non-availability of tracks and rail clips due to vandalism and theft.
- Increased trolley trips undertaken to assess the damage on the line, repair and declare the line safe to run trains.

  Impact on Train Operations: Train cancellations, train delays, increased derailment risk, increased risk of injuries and fatalities.

Signals:

- Signal failures
- Non-functional junction boxes, main cables, signal equipment rooms, points and axle counters.
- Corridors in degraded mode.
- Non-operational stations.

  Impact on Train Operations: Train cancellations, train delays, manually authorised trains, train speeds being lowered, and additional tasks allocated to TCOs.

Rolling Stock:

- Vandalised and stolen cab door locks, copper pipes on trains, vacuum gauges, power car batteries, windows, etc. leading to trains being taken in for repairs.
- Vandalised assets may fail in section before departure.

  Impact on Train Operations: Train cancellations and train delays

Electrical:

- Vandalised Overhead electrical equipment
- Increased maintenance and repairs due to traction rehabilitation projects started to repair lines.

  Impact on Train Operations: Train cancellations and train delays

Customer Services:

- No PA system to communicate to commuters about the train service leading to
- Non-functional alarm systems
- Non-functional information boards
- Stolen speakers

  Impact on Train Operations: Commuters missing trains, increase on incidents for Commuters and employees, reduced commuter safety, increase in break-ins and personal safety concerns

The case study above highlighted the ways in which the different infrastructure departments were affected by theft and vandalism. In particular, the case study showed that Train Operations was frequently the department that was affected in every instance.

Using the data analysed from theft and vandalism incidents and collected during the interviews, the table below was created to illustrate on a more detailed level, how theft and vandalism affects operational safety.

Table 3: The effects of Theft & Vandalism on Operational Safety

	Assets Affected	Latent Impact on Operational Safety	Department Affected
1	Rolling stock components in sections	Overtime, more callouts, fewer train sets available, train delays, increase in workload, increase in working hours, maintenance delays, increased error risk, extending emergency working sections and periods, longer and more frequent technology developments and new works notifications and submissions	Rolling stock, Train Operations
2	Rolling stock components in yards and sidings (staged)	Overtime, more callouts, increase in workload, increased error risk, longer and more frequent technology developments and new works notifications and submissions, increase in workload, increase in working hours, maintenance delays	Rolling stock, Train Operations
3	Civil infrastructure components in sections	Overtime, more callouts, increase in workload, increased error risk, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Perway, Train Operations
4	Civil infrastructure components in yards and sidings	Overtime, more callouts, increase in workload, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Perway, Train Operations
5	Overhead traction equipment in section	Overtime, more callouts, increase in workload, theft of OHTE cables, increased error risk, financial implication to rehabilitate assets	Electrical, Train Operations
6	Overhead traction equipment in yards and sidings	Overtime, more callouts, increase in workload, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Electrical, Train Operations

	Assets Affected	Latent Impact on Operational Safety	Department Affected
7	Train authorisation and control systems and equipment in sections	Breakdown of communication ability, use of manual train authorisation, reliance on cell phones instead on train radio, use of abnormal working, Overtime, increase fatigue risk, increase in workload, Train delays and cancellations, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Train Operations - drivers, TCOs, Section Managers, Telecoms, Signals
8	Train authorisation and control systems and equipment in yards and sidings	Overtime, more callouts, increase fatigue risk, increase in workload, Train delays and cancellations, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Train Operations Telecoms, Signals
9	Ancillary equipment, including public address (pa) systems, information boards and closed-circuit television (CCTV)	Affect overcrowding at stations, passengers don't know which platform to go to, information can't be shared, security monitoring affected, increase in passengers not feeling safe, increase in criminal activity, financial implication to rehabilitate or replace assets, longer and more frequent technology developments and new works notifications and submissions	Station operations, Telecoms, Train Operations

The table above indicates that almost all theft and vandalism incidents have a negative impact on operational safety in general, and Train Operations in particular.

Seeing as most assets affected form part of the critical infrastructure and the mechanical safeguards, their non-availability at different times and to different extents, leads to increased safety risk. The interviews indicated that the impact of theft and vandalism ranged from causing train delays to delaying planned maintenance.

It was highlighted during the interviews that the departments affected by instances of theft and vandalism regularly see their planned maintenance plans disrupted; often, this means that what was planned for does not materialise and additional resources must be redirected to repair the affected assets. The instances of theft and vandalism frequently further lead to extended hours on duty conducting repairs or bringing the assets back online. In some instances, the affected departments must wait for personnel from other departments to become available before a fault can be managed. It was noted by the persons being interviewed that instances of theft and vandalism tend to have a long turnaround time with repairs sometimes requiring over 12 hours of continuous work. This regularly means that teams must be re-allocated.

6. DISCUSSION

Railway transport was highlighted as a large complex sociotechnical and safety-critical system. The level of complexity sometimes translates to difficulties in understanding how risk factors converge to lead to significant hazards. As a large sociotechnical system, the railway environment is interaction dominated (Kyriakidis *et al*., 2018). This interaction dominance is a requirement for the optimal operation of the critical infrastructure that affect Train Operations and operational safety.

The results section of this report showed a significant theft and vandalism problem, which reached untenable levels during the COVID-19 lockdown period. The resultant damage destroyed entire corridors negatively affecting operational departments. The extent to which railway is interaction dominated means that incidents like theft and vandalism negatively affect optimal railway operations on several levels and to varying degrees. The most significant implications of theft and vandalism appears to be on train delays, train cancellations, increased fatigue risk (because of abnormal working, and possible overtime to repair damaged assets) and increased error risk. Even the processes and procedures involved in tackling theft and vandalism related challenges minimises the ability of infrastructure maintenance departments to focus on maintenance, compromising performance, safety, availability, and reliability (Ramuhulu & Chiranga, 2018). For instance, the personnel interviewed during this research project emphasised that one of the resultant effects of managing incidents related to theft and vandalism was cancelling planned maintenance activities and re-allocating personnel to restore vandalised or stolen assets. The re-allocations usually disrupt the roster, resulting in numerous changes. The challenges presented by roster disruptions and long turnaround times to manage incidents related to theft and vandalism also include difficulty ensuring that personnel receive adequate rest; this usually means that there will be an increase in the risk of fatigue. The increased fatigue risk frequently means that personnel may be more likely to perform inefficiently, increasing the risk of errors and increasing safety risk. Additionally, the challenges presented by theft and vandalism incidents also include more burdensome organisational and administrative tasks. The findings in this study thus confirmed Ramuhulu & Chiranga (2018)'s commentary that the ability of infrastructure maintenance departments to focus on maintenance was hampered by theft and vandalism. Indeed, the effects of theft and vandalism are far reaching, burdening the railway system on technical, administrative, organisational, and human factors levels.

The interviewees underlined that the emergence of scrap yards had opened pandora's box, creating an opportunity for criminal activity around the trading of copper to thrive. Their suppositions were in line with the research conducted by Fiumara (2015) who reported that there existed a worldwide demand for copper and that the production of this raw material was exceeded by its demand. As such, the theft of copper continues to be a significant challenge within the South African railway environment. The results indicated that cable theft was rife within the Signals, Telecoms and Electrical departments experiencing the largest and most consistent theft and vandalism challenges. The Signaling system with its assets, allow for safe operations of the rail network. The track system ensures that train control can detect the presence of a train while the signals allow safe communication with the driver. The unavailability of Signal and Telecoms equipment due to theft and vandalism will thus have an enormous impact on Train Operations. Effectively, when equipment designed to track and locate the train and maintain communication between train control officers and train drivers is non-functional, train authorisation processes cannot function adequately. This sometimes means that train control and authorisation procedures must function in degraded mode. A further impact of working in a degraded mode will be on the increase of fatigue and workload management related risks; the emergence of these risks will often increase the likelihood of human error, increasing the risk of occurrences such as collisions, trains passed at danger, and derailments. These types of occurrences are more likely to cause fatalities.

The results section showed that theft and vandalism can make it impossible to operate trains when the optic fibre network is non-functional because of it. The effect of a non-functional optic fibre network, in some instances, is the complete blackout of operational panels (with the whole visual display unit out). This often leads to train delays and cancellations, leading to more strain or stress on train control and/or train operations. The theft and vandalism of electrical or OHTE assets does not only affect the Electrical department but Train Operations. When several Electrical assets are stolen or vandalised, it can result in difficulty operating trains if the electrical system is not available. This often makes train cancelations inevitable. At times, the result is that Train Operations will have lines or sections that are not operational, increasing the need for the department to improvise and alter their train time tables.

Rolling Stock assets ensure that there is a fleet available to transport passengers safely. It also ensures that commodities are transported from one destination to another. The unavailability of these assets due to theft or vandalism poses a strain on Train Operations as train control will find it challenging to function with no trains to operate- requiring more improvisation to continue to operate trains.

The Pienaarspoort to Pretoria Case Study highlighted the impact of theft and vandalism on Train Operations and on PRASA's ability to resume services. The higher the number of assets to rehabilitate, the greater the time delays; these time delays frequently translate to operational delays. The affected infrastructure departments included the Signals, Telecoms, Perway, Electrical, and Rolling Stock departments.

7. CONCLUSIONS

The risk of theft and vandalism is an ever looming one within the South African railways that must be mitigated. The results of this study indicated that theft and vandalism often affected the safety management system, organisational management, and service delivery.

George et al. (2018) also reported that more instances of equipment theft and vandalism had resulted in section failures and unreliable train operations, leaving the passenger network in an unacceptable state. The findings of this research paper align with this assertion. It appears that indeed, theft and vandalism often decreased operational safety. In addition to the safety implications, the direct implications were on Train Operations; the theft and vandalism challenges recorded in the infrastructure departments, often directly limited the ability of Train Operations to operate trains.

On a risk and hazard level, the breakdown of safety barriers exposes the railway operations to additional hazards and risks such as derailments, collisions and injuries while also reducing systemic robustness and safety barrier effectiveness.

8. RECOMMENDATIONS

The recommendations for minimising the impact of theft and vandalism are:

- Increased security deployment and security visibility to protect assets,
- Identifying theft and vandalism hot spots so that security resources can be allocated accordingly,
- Fencing the railway network to enclose the open system,
- Investing in technological and infrastructural modifications such as:
    - Enclosing substations, e.g., using barbed wires, double latched locks, etc.,
    - Installation of intrusion detector systems at substations,
    - Installing anti-vandal technologies (especially on cables and points machines) such as alarms and monitors that go off when tempered with or cut,
    - Using drones for surveillance,
    - Installation of antivandal springs at the hot spot sections,
    - Investing in copper magnesium contact wire instead of pure copper contact wire,
    - Replacing catenary wire with tiger wire,
    - Substituting steel axle counters enclosures with concrete ones, and
    - Ensuring CCTV is always functional and visible.
- Implementing organisational adjustments such as:
    - Fatigue monitoring and workload management when personnel work overtime on repairing and managing theft and vandalism related incidents,
    - Conducting more trolley inspections (for Perway) to monitor sections of the railway line to ensure safe running of trains, and
    - Minimising personnel vacancies to manage fatigue risk.
- Controlling illegal settlements within the rail space,
- RSR support in the form of:
    - Roadshows and awareness campaigns that highlight the impact of theft and vandalism on the communities, economy, and railway transport,
    - Relaying the importance of a collaborative strategy to combat theft and vandalism to the organs of state, and
    - Establishing a theft and vandalism management committee including relevant stakeholders to ensure that all involved work towards the same goals.

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ANNEXURE A: Documents Reviewed

	Document
1.	GAUTENG_LIB-#49595-v1-ELECTRICAL_GN_ORGANIGRAM_2018
2.	GAUTENG_LIB-#69048-v1-Electrical_Department_Medical_Surveillance_North
3.	GAUTENG_LIB-#69054-v1-Electrical_Department_OHTE_Assets_Maintenance_Activation
4.	GAUTENG_LIB_-#69050-v1-Electrical Departmental Training Plan 2020-2021 North A Red, North C Green, North A Brown
5.	EMU Trainset Pantograph Learner Guide
6.	GAUTENG_LIB_-#69082-v1-Electrical_Rosters_Gauteng_North
7.	Attendance Register -Protection Refresher February 2022
8.	GAUTENG_LIB-#69029-v1-Perway_Gauteng_North_Annual_Medical_Surveillance_Tracking_Matrix_2022-2023
9.	GAUTENG_LIB-#69031-v1-Perway_North_Roster
10.	GAUTENG_LIB-#69032-v1-Perway_Training_Analysis_and_Matrix_GP_North_2022
11.	GAUTENG_LIB-#69033-v1-ROSTER_FOR_THE_STANDBY_-_Perway_Department_GN_Sept_2022
12.	Hercules Task Observation19-08-2022-093741
13.	Rebecca Task Observation19-08-2022-093046
14.	Repair Railbound attendance register
15.	Wolmerton Task Observation19-08-2022-093338
16.	GAUTENG_LIB-#69065-v1-Perway_Risk_Assessment_Gauteng_North
17.	GAUTENG_LIB_-#69072-v1-SIGNALS TASK OBSERVATIONS GAUTENG NORTH
18.	GAUTENG_LIB-#67844-v1-Gauteng Lines Under Abnormal Working
19.	GAUTENG_LIB-#69040-v1-Signals_Department_Medicals_Surveillance_
20.	GAUTENG_LIB-#69041-v1
21.	Training_for_Signals_Personnel_Gauteng_North
22.	GAUTENG_LIB-#69042-v1-Signaling_Personnel_Profile_Gauteng_North
23.	GAUTENG_LIB-#69043-v1-Signaling_Department_Structure_Gauteng_North
24.	GAUTENG_LIB_-#69071-v1-Telecoms Task Observation Gauteng North
25.	GAUTENG_LIB-#69070-v1-TELECOMS_PRETORIA_TO_PIENAARSPOORT_RISK_ASSESSMENT
26.	GAUTENG_LIB_-#69064-v1-Pretoria North CTC Trunky System Numbers
27.	GAUTENG_LIB_-#69047-v1-Telecomms Departmental Structure
28.	GAUTENG_LIB_-#69019-v1_TELECOMS READINESS AND CONDITION ASSESSMENT REPORT PRETORIA TO PIENAARSPOORT LINE DOC
29.	GAUTENG_LIB_-#538-v1-Telecoms_Master_Maintenance_Plan 2022-23
30.	GAUTENG_LIB_-#69046-v1-ROSTER FOR STANDBY - Telecoms Department Region August 2022
31.	Monthly report on theft & vandalism (showing all incidents per discipline, per depot)
32.	Security operational plans
33.	Recovery, maintenance & repair plans (should include roster & budget)
34.	Theft & vandalism hotspot tracking (with protection services)
35.	Annual summary of network availability
36.	Security incident data

37.	Theft & vandalism risk assessments (per department)
38.	Contingency plans in response to theft & vandalism
39.	Impact of theft & vandalism on network availability
40.	Records of train cancellations due to theft & vandalism
41.	Callouts due to theft & vandalism per department
42.	Overtime due to theft & vandalism per department
43.	Abnormal working due to theft & vandalism
44.	Maintenance backlog caused by theft & vandalism per department
45.	Railway lines that cannot be utilised due to theft & vandalism
46.	Number of trains/coaches that vandalised
47.	Occurrences (collisions, derailments, etc.) caused by theft & vandalism
48.	Corrective action plans to manage security risks

ANNEXURE B: Interview Questions

Theft & Vandalism Interview Questions

Job Title: _____

Organisation: _____

Gender: _____

Age: _____

Duration in current post: _____

1. Please briefly explain what the process for your department is when an instance of theft or vandalism occurs?

_____

_____

_____

_____

_____

2. How do instances of theft and vandalism impact your day-to-day activities and planning?

_____

_____

_____

_____

_____

_____

3. How often do you experience incidents of theft or vandalism?

_____

_____

_____

4. Which components are often stolen or vandalised?

_____

_____

_____

5. What, in your opinion, would be the most effective way to minimise instances of theft and vandalism?

_____

_____

_____

_____

_____

6. What role do you think your department can play in minimising instances of theft and vandalism?

_____

_____

_____

_____

7. Do you think there is a role that technological interventions can play in minimising instances of theft and vandalism or safeguarding the assets in your department?