Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P651-cd

TRANSNET FREIGHT TRAIN DERAILMENTS

Molifi Motshegare

Department of Construction Management, Nelson Mandela University, South Africa. E-mail: abram.motshegare@transnet.net

John Smallwood

Department of Construction Management, Nelson Mandela University, South Africa. E-mail: john.smallwood@mandela.ac.za

Transnet has strategies to manage train movements and investigate incidents to prevent derailments, and therefore, similar incidents should not reoccur. The aim of the study was to evolve a different approach for reducing the rate of freight train derailments experienced by Transnet by focusing on the methodology or processes that can be employed. A quantitative method was adopted, and operators and managers were surveyed using a self-administered questionnaire. The salient findings include operational challenges, including system failures; inadequate asset maintenance; and human behavior; inadequate communication; abnormal working of trains; poor track maintenance; signal passed at danger; and inadequate risk management. Conclusions include: ineffective investigations affect the accuracy of the findings, and the suitability of the recommendations, and the failure to implement recommendations from investigations contributes to the high number of train derailments and repeat occurrences. Recommendations include: Transnet to review depots' risk assessments effectively, and monitor implementation of the Board of Inquiry's (BOI) recommendations; all yards should have interlocking of points to avoid tampering, the system should automatically lock to avoid conflicting movements; maintenance resources should be adequate and ultrasonic inspection of track required to ensure compliance with applicable procedures.

Keywords: Derailments, Safety, Track Maintenance, Trains

1. INTRODUCTION

Transnet Freight Rail (TFR) is a world-class, heavy-haul freight rail company that specialises in the transportation of freight. It maintains an extensive rail network across South Africa that connects other rail networks in the sub-Saharan region with its rail infrastructure, representing approximately 80% of Africa's total. TFR assists in driving the competitiveness of the South African economy, and it is the lowest-cost, land-based freight option with the ability to transport diverse cargo. Transnet Freight Rail can transport diverse cargo types; however, it is most cost-effective for high density cargo, and the environmental benefits presented by rail are becoming more relevant in a greener South Africa. In South Africa, according to the Railway Safety Regulator (RSR) (2015) report, during the 2014/15 financial year, 592 train derailment incidents involving the movement of rolling stock were reported in South Africa. Out of 592 train derailments, TFR accounted for 305, while PRASA accounted for 33 and others for 254, and during the 2016/17 financial year, 386 derailments during the movement of rolling stock were reported (RSR, 2015). TFR accounted for 268, PRASA for 28, and other operators for 90 during that period.

According to the RSR (2016) report, the continued and increasing theft of overhead electric cables or signaling infrastructure equipment results in abnormal train operations with increased risk exposures, which result in operational occurrences such as train collisions or derailments (Illustration 1). An analysis of mainline derailments per operator shows that Transnet operating division TFR contributed 71.2% of all mainline train derailments.

Illustration 1. Freight train derailment.
Source: https://www.thesouthafrican.com/news

2. REVIEW OF THE LITERATURE

2.1. Rolling Stock and Rail Equipment Safety

Studies indicate that a combination of track and equipment failures cause more than half of all rail accidents around the world (Astin, 2011). RSR (2018) investigations into some of the major derailments that occurred in the 2017/18 financial year reveal poor maintenance of rolling stock as one of the main causes of train derailments.

Wang and Li (2011) focus on the ability of freight rail equipment to protect its operators and freight in the event of derailments and collisions. The main goals of crashworthiness are to preserve space for the operators in the case of a collision. The goal of Wang and Li's (2011) research was to explore train

sets and determine the level of structural crashworthiness that can be provided to the operators and freight.

Wang and Li (2011) argue that an appropriate collision scenario is selected by reviewing accidents involving high-speed equipment. Operator safety was assessed by examining the performance of the equipment in the chosen scenario using a one-dimensional lumped-parameter dynamics model to simulate a series of derailments and collisions. Key results include the maximum collision speed without loss of operator space, the distribution of crush throughout the cars of the train, and the severity of the deceleration experienced by passengers.

Rail defects are wide ranging in terms of variety and frequency due to higher axle loads and increasing traffic density in passenger and freight trains. Many of these rail defects, if left undetected, can develop into rail breaks, which lead to train derailments (Kumar et al., 2010).

2.2. System Failure and Railway Asset Maintenance (Operational Challenges)

Duvel and Mistry (2017) highlight that rail breaks have been the dominant immediate or direct cause of derailments on Oreline since the 2006/7 financial year. This reveals a strong upward trend in all derailments up to the 2010/11 financial year. They further state that almost 60% of all derailments over the past 9 years have been due to rail network failure (Illustration 1). The overwhelming majority of derailments due to rail network failure are due to rail breaks and thus the contribution of rail breaks to all derailments is 54%. Freight companies implement maintenance interventions to mitigate the risk of rail breaks and derailments (Liu Saat & Barkan, 2012), but a high number of derailments still occur annually on railways at Transnet.

2.3. Signals Passed at Danger

The operational contributing factor on derailments at Transnet under consideration in this study is that of a signal passed at danger (SPAD), which is defined as an incident where a train passes a signal displaying a stop indication or stop aspect, i.e., a red signal, without authorization (Kyriakidis et al., 2012). Signals being passed at danger are the most serious causes of railway accidents ascribable to operator error.

The 'red signal' is a common status in rail transportation. Rail crews encounter red signals in their service carriers daily. However, passing a signal at danger is a frightening event in view of its serious adverse impact and often catastrophic outcomes. Every railway system in the world is struggling to cope with this frightening event; however, it may be less in number. Indian Railways also have been cautiously acting, not only to reduce the number of incidences of SPAD but also to reduce its severity and very adverse consequences (Nayak & Tripathy, 2018).

2.4. Abnormal Train Operations / Manual Operations

Signal hardware failures are not an issue in rail systems. The signaling systems are designed to be fail-safe, and thus, component failure leads to a 'stop' indication. As a result, most signal-related accidents are related to human factors related rather than technology errors (English & Moynihan, 2007).

Nayak and Tripathy (2018) highlight that the station master's role is critical in train movements or running. Generic errors committed by them while performing yard functions are primarily for the following reasons:

- Wrong reception of train;
- Shunting in face of approaching train;
- Wrong operation / inattention;
- Wrong reception of train (no track circuit);
- Wrong procedure followed;
- Failure to observe the rules;
- Wrong procedure in reception of train in two-line station with no isolation;
- Failure to take gradient of station yard into account;
- Seeing of stabled train;
- Non-reversal of point in rear after receipt of train;
- Wrong system of simultaneous reception;
- Safe-work rule incomplete;
- Reception without ensuring clearance of line;
- Unauthorised taking off of signal;
- Use of defective block instruments;
- Communication failure;
- Signal put back;
- Cancellation of route, and
- Issuing of wrong authority.

2.5. Human Factors

Train crew errors and violation of train working rules include unsafe actions by the train crew such as the misinterpretation of signal aspects, disregard for cautionary signals, incorrect braking technique, failure to communicate correctly and a range of external and internal distractions. Organizational factors, such as a poor safety culture, poorly designed procedures, and inadequate monitoring or supervision are contributors to such violations.

Rail transport accidents are sad examples of human errors in full view, sometimes exposing the organization to a shameful situation. Basically, systems are not safe. It is therefore wrong to assume absolute system safety. It is the people who create safety while negotiating multiple layers of system goals with time and resource constraints. What a person thinks should have, or should not have been done, cannot explain people's behavior (Nayak & Tripathy, 2018). Furthermore, Nayak and Tripathy (2018) state that the unsafe act is an observable error such as choice of wrong procedure or task prioritization, violation of rules, and violation of methods, and new technologies do not remove human error: new technologies only change it. Human error is not the conclusion of an investigation: it is the starting

point. Why he/she did what he/she did that made sense to him/her is the big question.

Mainline and yard derailments rates are calculated with the same denominator values using the number of derailments on the mainline and yard track in the numerator. The mainline derailment rate increased from 1.16 derailments per million train miles in 1997 to 1.21 in 2001; this is a total increase of 4.4%, while the yard derailment rate increased 38.9% from in 1997 to 13.10 in 2001 (McKay, 2015).

2.6. Boards of Inquiry

Transnet boards of inquiry perform formal inquiries to investigate the circumstances surrounding incidents of serious magnitude or impacts on the business. This section focusses on the importance of investigating train derailments to identify remedial actions to prevent recurrences. The point of interest in this research is the recommendations and implementations after a board of enquiry had been held. Train derailment numbers remain high in South Africa despite the RSR and Transnet conducting investigations.

Cedergren (2013) notes that in many industries, a national accident investigation board conducts inquiries following major accidents. For safety improvements to be achieved, however, it is essential that the recommendations presented in these investigations are followed by the necessary actions. Cedergren (2013) determined that one of the areas in which potential improvements could be made is the link between analysis and recommendations in accident investigations. While it is obvious that an important task for the investigation board is to find out what happened and why, it is equally important to provide a clear and logically coherent description of the way this narrative is transformed into a roadmap for avoiding similar failures in the future.

In many industries, a national accident investigation board, conducts inquiries following major accidents for safety improvements to be achieved; however, it is essential that the recommendations presented in these investigations are followed by the necessary actions and that most recommendations issued by the investigation board are followed by some kind of action (implemented, initiated, or planned). Some one out of five recommendations did not result in any actions at all (Cedergren, 2013).

3. RESEARCH

3.1. Research method and sample stratum

A quantitative approach using a descriptive design and statistical analysis was adopted for this study. In quantitative research, the intention is to make sense of the world through measurement and numbers. Numbers represent aspects of the observable world, and quantitative research is a rigorous and systematic process for generating information about the world (Leedy & Ormrod, 2015).

The study entailed the completion of a self-administered questionnaire survey distributed per e-mail to a non-probability convenience sample of 65 potential participants across Transnet. Train operations' employees, as well as section managers and senior managers were selected for the sample.

The questionnaire consisted of two sections. Section A focused on the demographic information of respondents, and Section B on issues pertaining to the study. Section B consisted of 52 questions grouped into 8 categories from number 7 to 14.

47 Questionnaires were returned, however, six were not fully and satisfactorily completed, and were thus excluded from the analysis of the data, which equates to a net response rate of 63.1%.

The returned questionnaires were numbered, and the data was captured manually, and then analyzed using Microsoft Excel to compute frequencies and a measure of central tendency in the form of a mean score (MS) to enable interpretation of percentage responses to a five-point scale Likert type scale and an additional point in the form of 'unsure'.

In addition to the primary data, secondary data in the form of Transnet reports and documents, including but not limited to Transnet derailments, investigation reports, and Transnet annual safety reports were collected.

3.2. Ethical Considerations

As part of the requirements of Nelson Mandela University to comply with the Ethics Policy, the necessary interventions were taken. The key ethical issue being the protection of respondents and Transnet.

Permission to conduct the study in Transnet was obtained and approved at the level of the General Manager Talent and Transformation. Assurance was given that data collected in the study shall be protected and used only for the purpose of the study, and confidentiality of all participants was always guaranteed. Participation in the study was strictly voluntarily, and respondents had the right to withdraw from the study at any point in time by choosing not to return their questionnaires.

3.3 Research findings

Table 1 indicates the degree of concurrence with statements related to operational challenges contributing to train derailments in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that 8 / 14 (57.1%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree, as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates the role of the following in train derailments: misapplication of train working rules and procedures; non-compliance with train working rules; train drivers attending work after less than five hours sleep in 24 hours; the inability to deal with human factors; inadequate information; inability of train drivers to cancel their shifts due to personal circumstances; neglecting of train operating rules, and pressure on train drivers to complete tasks.

Table 1. Degree of concurrence with train derailments-related statements.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
Misapplication of train working rules and procedures are contributing to train derailments.	14.6	7.3	7.3	9.8	34.2	26.8	3.61

Most train drivers involved in train derailments did not comply with train working rules.	9.8	12.2	12.2	4.9	34.2	26.8	3.57
Transnet train drivers are not encouraged by their section managers not to attend work if they have had less than 5 hours sleep in the previous 24 hours.	22.0	12.2	7.3	14.6	29.3	14.6	3.34
Transnet has been unable to deal with human factors contributing to derailments, which have become the norm.	9.8	17.1	14.6	4.9	29.3	24.4	3.32
Inadequate information contributes to train derailments.	7.3	12.2	14.6	17.1	41.5	7.3	3.18
Transnet train drivers can't cancel their shift at short notice due to pressing domestic circumstances.	24.4	12.2	12.2	17.1	24.4	9.8	3.10
Most train drivers neglect train operating rules, which contributes to most train derailments.	9.8	19.5	17.1	7.3	31.7	14.6	3.05
Transnet drivers are rushed to complete tasks to stay on schedule or to meet a timetable.	12.0	17.0	19.5	14.6	19.5	17.4	3.01
Transnet has been unable to manage train passing signal at danger (SPAD), which contributes to most train derailments.	14.6	14.6	22.0	14.6	26.8	7.3	2.89
Transnet has been unable to stop non-adherence to longstanding train working rules, which has become the norm.	12.2	14.6	29.3	7.3	26.8	9.8	2.86
Transnet has been unable to stop unsafe work practices, which have become the norm.	7.3	24.4	19.5	4.9	34.2	9.8	2.84
Transnet train drivers are not discouraged to make potentially unsafe compromises because of equipment failure/mismatch, e.g., taking shortcuts or deviating from procedures.	19.5	24.4	19.5	12.2	19.5	4.9	2.52
Transnet train drivers are pressurised to report for duty despite feeling fatigued.	14.6	31.7	22.0	12.2	17.1	2.4	2.26
Train working rules are not easy to comply with.	12.2	53.7	24.4	2.4	4.9	2.4	1.62

Table 2 indicates the degree of concurrence with statements related to 'track manual operations and authorizations of trains' in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that 4 / 7 (57.1%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree, as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates the following: Transnet has a primary contingency plan when normal operations fail; management and employees are properly trained; Transnet has a team management readily available, and Transnet has developed the required competencies. It is notable that the MS of 'Transnet has been unable to stop unsafe manual operation practices, which have become the norm' is on the midpoint of the range, namely 3.00.

Table 2. Degree of concurrence with track manual operations and authorization of train-related statements.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
Transnet's primary contingency plan when normal operations fail is regarded as manual operation, and trains are authorised to enter section or pass signal at danger.	24.4	12.2	4.9	4.9	17.1	36.6	3.81
Management and employees are properly trained to operate and work safely on during manual operations.	12.2	7.3	7.3	14.6	43.9	14.6	3.58
Transnet has a team management readily available to manage manual operations.	12.2	7.3	7.3	19.5	39.0	14.6	3.53
The organisation has developed the required competencies and capabilities to manage manual operations.	17.1	4.9	9.8	24.4	26.8	17.1	3.50
Transnet has been unable to stop unsafe manual operation practices, which have become the norm.	17.1	19.5	19.5	2.4	24.4	17.1	3.00
Transnet has been unable to stop authorization of trains, which has become the norm and which results in most derailments.	22.0	19.5	29.3	9.8	9.8	9.8	2.50
Transnet has been unable to maintain train control methods as per train working rules, and trains are being authorised to pass signals at danger.	24.4	19.5	29.3	9.8	9.8	7.3	2.42

Table 3 indicates the degree of concurrence with statements related to track equipment failure, poor conditions of track and rolling stock in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that 6 / 9 (66.7%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree, as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates the role or likely role of the following in train derailments: inability to deal with the maintenance backlog; inability to deal with track equipment failures and the poor condition of track; inability to secure track equipment that ensures safe movement of trains; no dedication to instill a culture of operating excellence; inadequate safety standards and procedures, and the inability to stop unsafe work equipment.

Table 3. Degree of concurrence with statements related to track equipment failure, and poor conditions of track and rolling stock.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS

Transnet has been unable to deal with the maintenance backlog, which has become the norm.	7.3	2.4	14.6	9.8	34.2	31.7	3.84
Transnet has been unable to deal with track equipment failures and the poor condition of track, which has become the norm.	9.8	9.8	7.3	12.2	29.3	31.7	3.73
Transnet has been unable to secure track equipment that ensures safe movement of trains, which contributes to most train derailments.	9.8	9.8	9.8	12.2	34.2	24.4	3.59
There is no dedication within Transnet to instil a culture of operating excellence.	7.3	12.2	2.4	19.5	39.0	19.5	3.55
Inadequate safety standards and procedures (including those for operations, signalling, loading, inspection, maintenance, and management) contributes to most derailments.	12.2	12.2	22.0	9.8	34.2	9.8	3.08
Transnet has been unable to stop unsafe work equipment, which has become the norm.	12.2	19.5	14.6	14.6	22.0	17.1	3.03
Inadequate protection at level crossings (e.g., passive level crossings) contributes to most derailments.	9.8	26.8	14.6	7.3	34.2	7.3	2.78
There is flexibility for budget relocation and resources shifting within Transnet for monitoring and maintenance of rolling stock.	19.5	17.1	14.6	12.2	26.8	9.8	2.97
Lack of the employer's effort to ensure compliance with safety rules (including those for operations, signalling, loading, inspection & maintenance) contributes to most derailments.	12.2	17.1	19.5	7.3	36.6	7.3	2.97

Table 4 indicates the degree of concurrence with statements related to rolling stock defect reporting in relation to train derailments in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that all the MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates that: train crew, security, and technicians have in general reported safety defects on track infrastructure, rolling stock and electrical infrastructure; Transnet holds formal safety meetings on a regular basis with train crews; Transnet section managers conduct more than one safety observation per day; train drivers attend more than one formal safety meeting every month, and Transnet track inspectors and signal technicians conduct more than one track or fault inspection per day.

Table 4. Degree of concurrence with statements related to rolling stock defect reporting in relation to train derailments.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
Train crew, security, and technicians have reported safety defects on track infrastructure, rolling stock and electrical infrastructure during the past 6 months.	29.3	0.0	0.0	0.0	43.9	26.8	4.38
Each train crew has reported safety defects on track infrastructure, rolling stock or electrical infrastructure more than once in the past 12 months.	29.3	0.0	4.9	2.4	41.5	22.0	4.14
Transnet holds formal safety meetings on a regular basis with train crews to discuss track infrastructure, rolling stock and electrical infrastructure challenges.	17.1	12.2	2.4	14.6	34.2	19.5	3.56
Transnet section managers conduct more than one safety observation per day.	29.3	7.3	17.1	14.6	19.5	12.2	3.17
Train drivers attend more than one formal safety meeting every month to discuss track infrastructure, rolling stock and electrical infrastructure challenges.	24.4	12.2	14.6	9.8	31.7	7.3	3.10
Transnet track inspectors and signal technicians conduct more than one track or fault inspection per day.	29.3	9.8	12.2	17.1	24.4	7.3	3.10

Table 5 indicates the degree of concurrence with statements related to train operations risk management in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that 4 / 5 (80%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree, as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates that the following impact on train operations risk management, and derailments: equipment failure and the poor condition of track; inadequate protection, standards, procedures, and equipment to detect skew loads before commencing a journey; lack of hazard identification, and lack of Transnet's effort to ensure compliance with safety rules.

Table 5. Degree of concurrence with statements related to train operations risk management.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
Equipment failure and the poor condition of track contributes most to derailments.	9.8	2.4	7.3	9.8	43.9	26.8	3.95
Inadequate protection, standards, procedures, and equipment to detect skew loads before commencing a journey contributes most to derailments.	17.1	7.3	14.6	17.1	31.7	12.2	3.32
Lack of hazard identification before commencing any trip with load contributes most to derailments.	7.3	9.8	17.1	19.5	34.2	12.2	3.24

Lack of Transnet's effort to ensure compliance with safety rules attached to operations, signalling, loading, inspection, and maintenance contributes most to derailments.	7.3	4.9	31.7	17.1	29.3	9.8	3.08
Training in hazard identification process is part of a train driver's course, and hazards are assessed before commencing with the work.	26.8	14.6	14.6	14.6	19.5	9.8	2.94

Table 6 indicates the degree of concurrence with statements related to structural safety issues in terms of percentage responses to a scale of strongly disagree to strongly agree, and a MS ranging from 1.00 to 5.00. It is notable that 4 / 5 (80%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates that the following are important to avoid train derailments; protection against external hazards as well as inspection and maintenance of track drainage and side terrain; ensuring structural and functional integrity of the rolling stock, and adequate management within train operations to ensure safe and effective operations.

Table 6. Degree of concurrence with statements related to structural safety issues.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
Ensuring structural and functional integrity of the rolling stock is important to avoid train derailments.	2.4	0.0	0.0	4.9	39.0	53.7	4.50
Protection against external hazards as well as inspection and maintenance of track drainage and side terrain are important activities to avoid train derailments.	4.9	0.0	2.4	4.9	43.9	43.9	4.36
Ensuring structural and functional integrity of the infrastructure and its subsystem is important to avoid train derailments.	2.4	2.4	0.0	2.4	41.5	51.2	4.32
Inadequate management within train operations contributes to unsafe and ineffective operations.	4.9	7.3	12.2	9.8	46.3	19.5	3.62
Structural earthworks erosion and wash away due to flooding is the main contributor to train derailments.	12.2	12.2	31.7	14.6	24.4	4.9	2.75

Table 7 indicates the degree of concurrence with statements related to train derailment incident investigations, corrective action, and close-outs in terms of percentage responses to a scale of strongly disagree to strongly agree, and MSs ranging from 1.00 to 5.00. It is notable that 4 / 5 (80%) MSs are > 3.00, which indicates that in general, the respondents agree with the statements as opposed to disagree as in the case of MSs ≤ 3.00. The concurrence > 3.00 indicates that: train derailment incidents are investigated; incident investigations are given to senior management; the inability to implement recommendations after investigations contributes to re-occurrence of incidents, and recommendations are implemented to prevent re-occurrence.

Table 7. Degree of concurrence with statements related to train derailment incident investigations, corrective action, and close-outs.

Statement	Response (%)						
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	MS
All train derailments incidents are investigated to determine the root causes.	4.9	0.0	0.0	7.3	39.0	48.8	4.44
The incident investigation recommendations are given to senior management for implementation.	4.9	4.9	2.4	12.2	26.8	48.8	4.18
Transnet's inability to implement recommendations or close-outs given after investigation contributes to re-occurrence of train derailments.	12.2	14.6	0.0	12.2	31.7	29.3	3.70
The recommendations are implemented to avoid any reoccurrence.	7.3	14.6	17.1	14.6	36.6	9.8	3.11
Transnet's inability to manage train derailment incident investigations has become the norm.	12.2	22.0	24.4	12.2	24.4	4.9	2.61

4. DISCUSSION

The review of the literature identified and presented the contributing factors to train derailments, indicating how railway equipment, and human factors contribute to train derailments.

RSR investigations into some of the major derailments that occurred in the 2017/18 financial year reveal poor maintenance of rolling stock as one of the main causes of train derailments (RSR, 2018), which is underscored by Astin (2011).

The findings of this study are considered consistent with the findings of several related studies relative to the contributing factors or root causes of train derailments (Astin, 2011; Duvel and Mistry, 2017; English & Moynihan, 2007; Nayak & Tripathy, 2018).

The aim of the study was to establish the root causes of train derailments and to evolve a strategy to minimize such train derailments. The respondents' views indicate that track equipment failures, the poor condition of track, human factors, and maintenance backlogs, are the root causes of Transnet train derailments. These findings correlate with those of international studies (Astin, 2011; English & Moynihan, 2007).

The knowledge exists within Transnet to develop strategies to mitigate safety concerns once they are identified. However, it

is not clear that Transnet can recognize at an early stage when safety concerns arise. Challenges faced by Transnet train drivers while performing their duties require serious interventions. One of the recent major accidents that occurred in December 2019 clearly shows that there are many issues that are required to be addressed by Transnet management, such as track equipment failures, poor condition of track, and maintenance backlogs that resulted in train derailments. These findings correlate with those of international studies (Astin, 2011; English & Moynihan, 2007).

5. CONCLUSIONS

TFR is committed to safety, has a safety system, program, procedures, and protocols in place. However, the accident statistics indicate inadequacies therein, the potential to improve thereon and reduce accidents.

Train derailments are attributable to operational challenges, which include system failures, and lack of railway asset maintenance, human behavior, and inadequate communication.

Increasing train derailments are attributable to: poor track equipment, inadequate maintenance, and SPAD; inadequate risk assessment and risk management, and continuing abnormal working / manual operation of trains.

Finally, it can be concluded that a culture change is required, which includes the adoption of best practice, and 'closing out' investigations by ensuring that recommendations are implemented, maintained, and continually reviewed to prevent the re-occurrence of accidents.

5. RECOMMENDATIONS

If Transnet Corporate Safety Office Department does not already have the power within its scope of activities to review depots' risk assessments and ensure risks are properly managed, they should have, and if they do not have powers to monitor the implementation of the BOI's recommendations, they should also have, because these will assist in managing train derailment incidents. Further to these recommendations, it is critical that Transnet explore the possibilities of establishing an independent railway safety board so as not to rely solely on the RSR, which is more reactive than proactive. The purpose of the independent railway safety board would be to advance Transnet trains' safety by being impartial and monitoring the implementation of recommendations. The importance of independence is a key factor that allows for transparency and independence, encourages openness and honesty, and eliminates the need to apportion blame.

The Transnet Corporate Safety Office Department must adopt best practices in terms of accident investigations as a tool to ensure that similar accidents do not re-occur. The Norwegian Safety Investigation Authority (NSIA) has developed a common framework and analysis process for carrying out systematic safety investigations (NSIA, 2021).

The framework describes how to collect, organise, analyze, and interpret information and data arising from investigations of accidents in a systematic way - how to understand accidents, why they occur, and how safety can be improved to prevent accidents in the future. Adoption of this framework is likely to contribute to Transnet improving its accident investigation process, response, and the prevention of re-occurrences.

Some of the yards are exposed to security-related risks and vandalism. It is important that Transnet ensure that all yards have interlocking of points operation such that when equipment is tampered with, the system should automatically lock to avoid conflicting movements and unnecessary derailments. Most derailments occur due to vandalism or tampering with operated points, which very often cause derailment. The use of interlocking of remote-controlled points should include tracks at shunting yards used for train movements.

It is critical that maintenance resources are adequate to ensure compliance with Transnet's policies or procedures. If it is impossible to ensure adequate resources and there is a reported infrastructure safety concern relative to a line, action must be taken to ensure that points of the lines and tracks where the minimum infrastructure safety requirements cannot be maintained are clamped, or the line is closed. Ultrasonic rail inspection of track must be performed as per the applicable procedure to ensure that all unsafe conditions are identified, and Transnet must become proactive in terms of ensuring proper maintenance of railway equipment. It is imperative that rail cracks be detected, and the frequency determined by means of rail age and loads before dangerous ruptures occur.

Further recommendations include that Transnet should include the necessary items, which are critical to accurately benchmark, use the requisite guidelines to assess the safety of running lines, and use the requisite guidelines to conduct train derailment investigations. Doing so should provide a consistent set of data for trend analysis and benchmarking.

REFERENCES

Astin, G. (2011) *Assessment of freight train derailment risk reduction measures: Part A final Report*, Stockport, Det Norske Veritas (DNV) Ltd.

Cedergren, A. (2013) Implementing recommendations from accident investigations: A case study of inter-organisational challenges. *Accident; Analysis and Prevention 53*, pp. 133-141.

Duvel, J., and Mistry, K. (2017) *Improving rail integrity on the Sishen-Saldanha line 2017*. Cape Town, South Africa.

English, G.W. and Moynihan, T.W. (2007) *Causes of accidents and mitigation strategies*. TranSys Research Ltd.

Kumar, S., Gupta, S., Ghodrati, B., & Kumar, U. (2010) An approach for risk assessment of rail defects. *International Journal of Reliability, Quality and Safety Engineering 17(4)*, pp. 291-311.

Kyriakidis, M., Hirsch, R. and Majumdar A. (2012) Metro railway safety. *Safety Science 50(7)*, pp. 1535-1548.

Liu, X., Saat, M. and Barkan, C. (2012) *Analysis of causes of major train derailment and their effect on accident rates. Transportation Research Record: Journal of the Transportation Research Board 2289(1)*, 154-163.

McKay, M.P. (2015) Fatal consequences: Obstructive sleep apnoea in a train engineer. *Annals of Family Medicine,13(6)*, pp. 583-586.

Nayak, S. and Tripathy, S. (2018) A critical evaluation of impact of human error: Rail System Failure with a View to Enhance Safety. *IOP Conference Series Materials Science and Engineering 390(1)*:012024 OI: 10.1088/1757-899X/390/1/01202.

Railway Safety Regulator (2015) State of Safety Report 2014/2015, 57. Available at: https://nationalgovernment.co.za/...annual/.../2015-railway-safety-regulator-(rsr)-annu (Accessed: 21 October 2020)

Railway Safety Regulator (2016) *State of Safety Report* 2015/2016, 15-28. Available at: https://nationalgovernment.co.za/...annual/.../2016-railway-safety-regulator-(rsr)-annu (Accessed: 21 October 2020)

Railway Safety Regulator (2017) *State of Safety Report* 2016/2017, 38-42.Available at: www.rsr.org.za/.../State%20of%20Safety%20Reports/RSR%20State%20of%20Safety (Accessed: 21 October 2020)

Railway Safety Regulator (2018) State of Safety Report 2018/2019, 58.Available at: www.rsr.org.za/.../State%20of%20Safety%20Reports/RSR%20State%20of%20Safety (Accessed: 21 October 2020)

South African National Standards. (2009) *3000-1:2009 - Railway Safety Management*. Pretoria, SABS Standards Division.

Norwegian Safety Investigation Authority (2021) *Framework and analysis process for systematic safety investigations*. Oslo, Norwegian Government.

Transnet (2019) *Board of Enquiry Report, 2019a–2019f*. Johannesburg, South Africa.

Transnet (2017) *Integrated Annual Report* 2016/17, 77-95. Available at https://www.transnet.net/InvestorRelations/AR2017/Transnet%20AFS%202017.pdf (Accessed: 12 September 2020)

Transnet (2016) *Train working rules and general operating instructions*. Johannesburg, Transnet.

Welman, C., Kruger, F. and Mitchell, B. (2005) *Research methodology*. Cape Town, Oxford University Press.

Wang, W. and Li, G. (2011) Category of derailment mechanism and prevention for high-speed vehicle. *Journal of Transportation Engineering 137*, pp. 730-737.