A SYSTEMS APPROACH FOR USING HUMAN FACTOR MANAGEMENT STANDARDS TO PREVENT RAIL ACCIDENTS IN SOUTH AFRICA

Dr. Millicent Tlakula

Journal Article

Masters in the Management of Technology and Innovation

at

The Da Vinci Institute for Technology Management

Academic supervisor: Linda Chipunza, DPhil et Litt

2023

ABSTRACT

A systems approach for using human factor management standards to prevent rail accidents in South Africa

Background: Safety management is a critical factor in any operation, specifically in operations that can result in catastrophic loss of human life, such as the railway industry. Over the years South Africa has been experiencing lots of railway accidents, with 71% being attributable to human error. To manage the human error as a prevalent cause of accident in South Africa, the RSR implemented SANS 3000-4, Human Factor Management (HFM) Standard in 2011(RSR, 2019).Eleven years since the promulgation of the HFM standard, railway accidents are still occurring at an alarming rate. This study aims to find a systems approach for using HFM standards to prevent railway accidents. The study reviews the literature with the research questions examining systems thinking approach, technologies associated with railway operations, the governance of railway industry in South Africa, review of Board of Inquiry (BOI) reports of railway accidents, the human work performance systems model as well as the elements of HFM standard.

Methods: Mixed methods in the collection and analysis of data to ensure the fulfilment of the aim and objectives of the study was employed. The methodology followed a pragmatist philosophy in the extraction of knowledge for the study. The target population in this study was safety critical employees working at PRASA, Metrorail, who were deemed suitable to participate in the study.

Results: A total of 278 respondents from the HFM survey and six participants from a focus group were included in the study population. The results of the study indicates that poor maintenance and delipidated infrastructure are mainly to blame for railway accidents in South Africa. Human factors accounted for a lesser percentage (49%), compared to other causes. Other contributory factors were training, supervisory issues, resource management and governance issues.

Conclusion: The study shows that infrastructural, maintenance, resource management, training, supervisory issues, governance and risk management form significant elements in the causation of railway accident. These factors contribute a fertile ground where human factors (as a prevalent cause of accident) will continue to thrive, despite the best implemented tool to manage the very human factors. Therefore, to address the challenges, a holistic approach, systematically applied across the railway industry, is required.

Keywords: human factor management, railway safety management system, railway transport, safety critical workers, systems thinking

1. Introduction

Safety management is a critical factor in any operation, specifically in operations that can result in catastrophic loss of human life, such as the railway industry. Over the years, safety regulations have been continuously implemented and improved in countries that rely on rail for passenger movement. Within South Africa, the railway industry has seen major developments since the promulgation of the National Railway Safety Regulator Act (16 of 2002) (the NRSR Act). With the NRSR Act in place, the Railway Safety Regulator (RSR) came into effect and assumed the responsibility of being an independent safety regulator of railway operators within South Africa. Despite South Africa's advancements in railway safety standards, the volumes of technical and engineering standards that have been drawn up, the rail incidents and accidents seem to be on the increase. In the year 2017/2018 human error accounted for more than 71% of accidents.

To manage the human factor as a prevalent cause of accident in South Africa, the RSR implemented SANS 3000-4, Human Factor Management (HFM) Standard in 2011(RSR, 2019). The purpose of HFM is to reduce occurrences attributable to human error and, in addition, mitigate the risks associated with these errors in the railway industry. The objective of this standard is to enhance the railway Safety Management System (SMS) and to assist railway operators to proactively manage the risks associated with human actions (RSR, 2019). Eleven years down the line, the rate of railway accident in South Africa has not changed. Hutchings and Thatcher (2019) found that South Africa has on average 4 500 railway occurrences annually, resulting in fatalities, injuries and damage to rolling stock. The State of Rail Safety Report 2017/2018 shows that there has been an increase of 1.6% in train collisions compared to the previous reporting period (RSR, 2019). Even though the 2021/2022 State of Rail Safety Report shows a decline of 40% in railway accidents compared to 2019/2020, the industry is warned not to celebrate this factor, as it is mostly attributed to markedly declined train kilometre travelled (Kgomari, 2022).

This study mainly focuses on developing a prevention system from an understanding of the role played by human factors in the continued prevalence of accidents within the railway operators of South Africa. In so doing, this research investigates the phenomenon in the context of the HFM standard (SANS 3000-4) framework that is used by the railway industry in South Africa. The study was anchored on systems thinking theoretical framework.

History of South African Railways : To achieve the objective of the study, in-depth review of studies conducted by other authors were analysed. Firstly, the background history into the South African railway industry, was explored. South African railway industry is 163 years old (DoT, 2022). The industry has undergone lots of evolutionary changes since inception in 1859. The more recent being in the 20th century, where it was set apart by unprecedented industrial and economic changes through the birth of South African democracy in 1994.With this development, PRASA (born 1990) has historically experienced a lack of investment, resulting in dilapidated rail infrastructure and rolling stock (George, Mokoena & Rust, 2018). With the change in the political structure, there was a requirement that the resources of the state serve the entire population of South Africa, as opposed to the previous regime (Apartheid), which was designed to serve only the minority. This new political construct came with an increased need for better and more railway infrastructure for economic and public transport. Fast forward into the 21st century, the railway industry is still addressing the inherent effects of inadequate infrastructure development and maintenance which had accumulated over the years (Department of Transport, 2015).

Key technologies in railway: The author also explored the complexity of the railway infrastructure requirements that allow coherent operations of railway systems, and its inherent key technologies that are central to the system operating in a safe manner. Railway systems, from manufacture to operation, are highly technical in terms of engineering works and human resource requirements. The railway system comprises a broad and complex infrastructure characterised by technological and material properties (Fourie & Zhuwaki, 2017). The railway infrastructure as described by Jidahi (2015) comprises the following components: "the tracks (railway lines), Perway (bridges, platforms), signalling technology (robots, points machines and relay rooms), telecommunications systems (surveillance cameras), PA systems and Centralised Train Control (CTCs) and the electrical systems (cables, power lines, gantries)". Understanding the aforementioned railway components is central to the study as it links with the functions of safety critical workers with whom the HFM standard is concerned.

Systems thinking: A systems thinking theoretical approach was also explored through the lens of various authors, including Senge (1990), Sweeney and Sterman (2000) and, more recently, Arnold and Wade (2015). The three elements of a systems thinking model, namely interconnectedness of various elements, synergism of the elements and the quest to bring about a desired goal, were explored. From the various definitions, it was argued that systems thinking provides a holistic way of seeing things. It provides a lens within which the interrelated and interdependent elements form collective entities. It is characterised by synergistic interactions, thereby allowing combined interaction of the various elements to produce a total effect that is greater than the sum of the individual elements. This led to the proposal to utilise systems thinking approach to mitigate railway accidents in South Africa.

Board of Inquiry Reports Summary – Railway accidents in South Africa : PRASA's trains have been identified as the greatest threat to personal safety on the country's rail networks, according to the RSR's report of 2018. Some of the railway accident reports alluded to possible causative factors, for example miscommunication between driver and controller noted as the cause of the Pretoria train crash (Timeslive, 2019), and deadly derailment due to train track vandalism, which was noted by Timeslive (2019). With each railway accident, the RSR is mandated to conduct an enquiry and to release a report on the causal factors of the accident. Over the years, the RSR has reported that in a number of forums where train occurrences were discussed, human factors have been noted as the biggest contributor to the high number of incidents (News24, 2015). The human factors listed include drivers not adhering to rules of operational speed restrictions, train control officers not complying to the rules, train drivers found to be inexperienced, little supervision from supervisors and line managers and reportable medical conditions not disclosed by affected staff members (Bouwer & Hubinger, 2014).

On the other hand, PRASA leadership has blamed vandalism and cable theft as the major contributory factor to the accidents. The effect of lack of electricity due to cable theft results in the use of a manual signalling process. Pressreader (2018) observed human error in the manual signalling process as a major cause of accidents involving PRASA commuter trains over the past few years.

Understanding role of human beings in safe railway operations: In trying to manage human errors in the railway, research has been conducted to delve into a deeper inquiry on human factors and human performance in the railway industry, with the aim of investigating the influence of people performing tasks on the railway system. In their UK-based research, Majumdar, Ochieng and Kyriakidis (2015) concluded that human performance is a significant contributor to railway incidents and accidents. Interpretation of the work system model is demonstrated using a train driver who has to contend with many aspects to ensure safe railway operation. The train drivers' input into their task includes information gathered by track observation, signal aspects, transmitted information by train cabin instruments or radio communication. The output would be controlling movement of the rolling stock to get to the desired destination. In ensuring a successful output, Hammerl, 2011, argues that the following factors should be considered. Firstly, the human element of the system which comprises specific individual factors such as the individual's health status, emotional liability, age and other job-dependant factors, which include skills, experience, motivation, fatigue and safety awareness (Hammerl, 2011). Secondly, performance-shaping factors, which are defined as variables that may affect human performance in systems that rely on humans (Arigi, Kim, Park &Kim 2019). The performance shaping factors include personal, organisational and physical environmental factors.

Personal factors were explained by Majumdar, Ochieng and Kyriakidis (2015) to be those characteristics that affect individuals' performance and are strongly related to the precise moment of an operational occurrence. Examples include levels of stress, distraction, fatigue and vigilance. Besides personal factors, organisational factors also play a role in shaping performance of humans within a work system such as the railways. Organisational factors include the factors defined and controlled by an organisation, which include roster planning, leadership, education, training, social environment, safety culture, workplace standards, rules and guidelines and task design (Hammerl & Vanderhaegen, 2012). An example of an organisational factor that has emerged as a contributory factor to accident in PRASA Rail is the issue of train driver training (Bouwer & Hubinger, 2014).

The physical working environment can also give rise to workload, including noise vibrations or an uncomfortable cab climate (too hot, too cold, draughty). The train driver is also exposed to a demanding psychosocial working environment, which includes solitary work and limited opportunities for social contact with colleagues. The stress from the psychological effects of train driving has been studied intensely by Samerei, Aghabayk and Akbarzade (2020), who concluded that "conducting and controlling the metro trains is a psychological task that requires long-term work and intense concentration to pay attention to signals and stimuli. Failure to pay attention to train and metro drivers' psychological needs will lead to mistakes, and an accident may occur."

Unpacking Human Factor Management Standard -SANS 3000-4: The RSR, together with a railway industry specialists, in 2009 sought to formulate a legislation framework that would assist railway operators to manage human factors. This step was taken to manage the complexities that surround human factors within the railway operations in South Africa. Benchmarking with Canadian and Australian standards, the work put together led to publishing the Human Factor Management Standard, SANS 3000-4:2011, by the SABS in 2011. According to the RSR, this standard aims to provide railway operators with the minimum requirements needed to manage human factors to reduce occurrences attributable to human error. With the standard in place, railway operators are guided on how to optimise human capital by mitigating the risks associated with human factors in the workplace to acceptable levels. HFM standard is centred around the external factors impacting the human task performance model alluded to above. The HFM standard recognises three factors which affect the performance of safety-related workers, namely: first, physical environmental factors; second, organisational and psychological factors; and, third, human factor in design (SANS 3000-4:2011).

SANS 3000-4:2011 mandates railway operators to establish, develop, adopt, document, implement and maintain policies, processes and procedures for conducting risk assessments that relate to the management of the stated factors. The physical environmental factors which include noise, vibration, lighting, thermal environment and hazardous substances and agents. The second factor, human factors in design (HFID) SANS 3000-4 2011:16, includes the matching of tools, equipment, machines, systems, tasks, jobs, work processes, workstations and environments to the physical and psychological capabilities and limitations of people. The standard states that poor design, which includes awkward body positions, excessive forces (handgrip, lifting, pushing or pulling), manual material handling and repetitive strain, might expose employees to hazards that could impact on safe railway operations. Lastly, the HFM standard requires the operators to deal with the following components that pertain to organisational and psychological factors. The listed factors to be managed have been categorised as recruitment and selection; training and development; medical surveillance; use of medication; chronic diseases; fitness for duty; fatigue management substance abuse; pregnancy; and employee wellness.

2. Results

The first results findings relate to the safety critical workers' demographic profile, which include job category, qualifications, gender, age and job experience. The demographics also offer information about the profiles of individuals who responded to the HFM survey. **Gender:** The majority of the respondents were male, representing 72% (161), and females representing 28% (63) of the total sample. **Age**: HMF study average age was between 25 and 45 years. **Educational qualifications:** The majority of the respondents revealed that their highest qualification is a certificate or diploma, representing (57.1%), this was followed by those who indicated they have a matric at (30.8%), employees with degrees were (6.3%), qualification below matric were (3.1%) and lastly, employees who indicated they have a post-graduate degree, represented (2.7%) of the total sample. **Work experience**: The majority of the respondents (59.8%) indicated that they have work experience of 16 to 25 years, followed by (17.0%) of those who indicated their work experience as between 11 to 15 years, (8.9%) of the respondents indicated their work experience as between 6 to 10 years, and (13.0%) indicated having work experience above 26 years, lastly, (0.9%) had work experience of less than 5 years.

The next results are presentation of railway accidents from a possible causative factor perspective, the contribution of the human factor element, as well as the type of human factors leading to railway accidents. **Likely causes of railway accidents**: poor maintenance ranked highest at (89,2%), followed by equipment malfunction at (77.2 %); and lastly human factors at (49.0%). **From the results regarding the pre-existing conditions**, it is evident that dilapidated equipment and system at (93.0%), play a major role in accident causation in South Africa. The focus group findings were in support of the HFM survey questionnaire findings and echoed the need for railway industry to condemn dysfunctional equipment. From the results of **human factors as cause of accident**, the following were found: technical and operational errors contributed (86.0%), inattention (78.9%), fatigue (75,9%) and complacency (45.0%). The focus group discussion pointed to the issue of non-structured apprenticeships programs and over reliance on automation as contributory causes to the human factor causes of railway accidents.

The findings from **supervisor related issues as cause of accident** were as follows : Failure to correct problems was the highest at (47.7%), followed by inadequate supervision at (38,9%), planned inappropriate operations at (25.4%) and lastly supervisor violation at (17.4 %). The focus group concluded that there was need for tightening supervisory roles through close monitoring, refresher training, and tests of competences. Respondents were also required to state **the extent to which organisational influences impact on the management of railway safety**. From the results obtained organizational processes (standards, policies, procedures) contributed above 80%, financial management contributed (77,0%) and safety climate (60.0 %). As well, the respondents were presented with a list of **risk management processes** from which they were required to analyse the extent to which they had been effective in promoting HFM at their workplace. From the results obtained risk identification effectiveness was rated at (66.0%), risk evaluation at (68%), risk control at (58%), and lastly risk communication at (56%). The focus group experience is that there are weaknesses in the risk management processes, operators are less conscious about operational risks resulting in accidents. They opined that gap of risk management could be avoidable adoption of a total quality management of all risk and training. Lastly, safety critical workers were presented with a list of **railway governance authorities** from which they were required to state how effective or ineffective these authorities are in the implementation of HFM standards. The findings are as follows: RSR's effectiveness was at (85,13%), followed by DoT at (43,94 %), senior managers at (26,12 %), board of directors at (19.36 %) and lastly organizational CEO at (11.71%).

3. Discussion of results

Emerging from the findings are demographic profiles of Metrorail's safety critical workers, which show that the company employs predominantly males, aged between 36 and 45 years, who have been working in the organisation's train operations division for over 15 years. Most of the safety critical workers have a trade-specific diploma or higher certificate, indicating that the general workforce is qualified for the operations. The dominant male representation in SA is comparable to other countries e.g. UK's 16% of female representation (Ginn, 2019). This finding led to the conclusion that there is still a substantial shortage of female safety critical worker representation. The results from the educational qualifications as discussed above is a demonstration that the railway industry in SA suffers from lack of railway operations academic skills. Mukwena (2018) agrees that there are no sufficient railway-specific courses offered in universities and colleges in South Africa. Bouwer and Hubinger

(2014), argued that there has been a deterioration in the standard of commuter train driver training as evidenced by the reduction of train driver training from two years to six months and the fact that most railway operators are now managing their own training. To further demonstrate the deteriorated operating standard, it is an important fact to note that prior to 1990, commuter train drivers were sourced from highly experienced freight train drivers, a practice which has now stopped (Bouwer & Hubinger, 2014). Based on the results of the study and the literature review as stated above, an evaluation that safety critical workers qualification and training skills is a contributory factor to railway accidents cannot be ignored. Looking into the results of job categories that participated in the study, it is also evident from the study demographics that there is a lack of representation in all infrastructure-related safety critical workers in the electrical, signalling and Perway departments, which are core technologies in ensuring safe railway operations. This shows an imbalance in skill sets and reveals that train drivers are at the core of PRASA operations.

The dilapidated, aged, poorly maintained South African railway network remains a fertile ground for railway accidents to occur. The aged infrastructure is a pre-cursor to some of the human factor-related causes; for instance, due to the infrastructure problems, signals do not work properly, leading to operatives working in degraded mode. It is within this degraded mode that most technical and operational errors occur. In the focus group discussions, there was a lively debate with regard to malfunction of train or poor maintenance being likened to human-related factors. Jidayi (2015), supports this finding in stating that South African railway transport systems have been suffering from reliability challenges due to its aging infrastructure and high utilisation of its physical assets. The aging infrastructure coupled with lack of an effective maintenance strategy as opined by Mukwena (2018), can lead to major compromise of the railway infrastructure.

Although, from the perspective of safety critical workers, human factors are viewed as not being a pre-dominant cause of railway accidents, their prevalence remains high at 49%. Several human factor-related causes of accidents were explored; the topmost were technical and operational errors (86,18%), inattention (78,93%) and fatigue (75,90%). Focusing on the inattentiveness, it is important to note prevalence of accidents due to intention elsewhere as noted by Wundersitz (2019) who observed that distraction contribute to 31% of road accidents in Australia. To substantiate this Dambuza, 2017 opined that factors that contribute to driver distraction and inattentiveness originate from the technologies introduced to improve driver performance. Dambuza's assertion is comparable to the focus group finding which stated that “We thought that automation was going to reduce accidents, but alas, it has not. We were trained during the old days when there were no advanced automations which are now present; as olden-day operators, we are used to be checking the signals and exercising caution. It is different from the way those modern-day trained operator’s who put over-reliance on the automation, and are caught in the malfunctions of the robots …”

On the issue of corporate governance, the results depict low confidence in the corporate governance structure of PRASA to manage accidents within the railway sector. Corruption, which is rampant within the organisation, diverts resource utilisation, leading to shortages in vital structures that allow safe railway operations (www.pmg.org.za). The public protector report entitled “Derailed”, details the maladministration relating to financial mismanagement, tender irregularities, and appointment irregularities (Public Protector Annual Report, 2015/16). Due to the lack of financial resources in PRASA, it is a common scene for people to run across the tracks, hang out of doors and windows, travel between carriages or even ride on the roof, thus increasing the number of accidents on the railway (Polit & Beck, 2014). Compromised investment in technology and manual authorisations of trains result in many safety violations, which are responsible factors for multiple railway accidents within PRASA, Gauteng region (Williams, 2019). The manual authorisation usually occurs as a result of cable theft, poor maintenance or a lack of spares for the automatic signalling system, all of which are due to poor governance.

4. Reflection on findings from a Technology, Innovation, People and System (TIPS) model perspective

Observing HFM study findings, the researcher used the Da Vinci TIPS model lens to test PRASA’s current competitive performance. TIPS is an acronym for a Da Vinci model which constitutes four critical management areas, namely technology, innovation, people and system. TIPS specifies that any organisation that strives to be globally competitive must be extremely competent in managing the above-mentioned areas of management.

Technology and innovation: When looking at the aspect of technology, it is a notable fact that technology automates the most complex of processes, be it in communication, education, medicine or any other industry. With the application of technology, critical and time-consuming processes can be executed with ease and in less time, allowing efficiency and speed. There are various methodologies that organisations can employ to choose the appropriate technological tools. From the results of the study is it evident that PRASA is experiencing high rates of accidents due to poor state of maintenance, dilapidated and decaying railway infrastructure, and human-related factors such as fatigue. These factors are easily manageable through technology. Technology can allow access to systems such as asset management and predictive maintenance tools, which in turn will improve timely decision-making on issues that affect safety and resource availability and will assist the operator to anticipate systems challenges as they emerge. Technology and innovation can serve as a catalyst in ensuring that PRASA gains access to systems that have interconnected technological solutions. To remain relevant and competitive, PRASA should endeavour to move from its current manual operations to technology-based smart railways. A smart railway is defined by Fraga-Lamas, Fernández-Caramés and Castedo (2017) as a technologically advanced approach to efficiently manage railway operations through the sharing of rail data across rail infrastructure components, such as passengers, control centres, ticketing department and freight. Fraga-Lamas *et al.* (2017) advanced the fact that smart railways are integration of the latest technologies, including Internet of Things (IoT), big data, cloud, analytics, artificial intelligence (AI), global positioning system (GPS) and machine learning (ML) to make rail operations more efficient and accurate. Technology in the innovation space reflects agility, which is an essential component to have in an organisation like PRASA. At its current state, there is no evidence to prove that PRASA is an agile organisation. To the contrary, PRASA is on the verge of total collapse.

Innovation and people: In today's business environment, new companies are introducing technologies that have the potential to reshape entire industries and how people conduct their day-to-day lives. The capacity to create value through the development of new customer experiences, products, services, technologies, processes and business and delivery models is one of the keys to profitability, growth and survival. The 2010 Global Railway Review report tells how the UK turned around their railway systems through innovation. Around 2002, the UK railway system had lost the confidence of the nation; train schedule punctuality was running at below 80% while the number of broken rails approached 1,000. Following innovative interventions, punctuality improved to 94%, while broken rails fell to 152, and safe railway operations were restored (Global Railway Review Report, 2010). What the UK faced then is not different from what PRASA is facing today. To combat its current state of disaster, PRASA has adopted a Railway Modernisation Programme, which promises a state-of-the-art rail service which entails modern, faster, reliable and cost-efficient train services. The programme focuses on the modernisation of stations and fleet. For the fleet management, PRASA appointed Gibela Rail Transport Consortium (Gibela) to supply 3,600 new Metrorail coaches at a cost amounting to R51 billion over a 10-year period (2015–2025) (PRASA, 2021). Results of this intended innovation are yet to be realised. Even though some fleets have been delivered in Gauteng and Western regions, systemic factors that Metrorail has not addressed have already emerged, reversing gains from this innovation. Tidd and Bessan (2014) argued that the innovation process in organisations needs to be managed in a systematic or integrated way. This would require strategic leadership and direction, and building an innovative organisation, which entails having a structure and climate that enables people to be innovative, and networking for innovation.

For PRASA to achieve its innovative goal of modern, faster, reliable, and cost-efficient train services, it requires a robust portfolio of leaders who are ready to engage employees, push forward growth strategies, drive innovation and work directly with customers. A 2010 study by the Harris Group (2010) indicated that executives see a culture of innovation as crucial to not only growing their business (95%) and profitability (94%) but also for attracting and keeping talent (86%). Allowing employees space to be innovative is a great master tool for employee engagement. Sun (2018) referred to employee engagement as employees' physical, cognitive, and emotional input in the work. Farndale (2015) argued that certain job resources (financial returns, team atmosphere, participation in decision-making) positively affect employee engagement.

Although employee engagement was not measured, it can be inferred from some results of the study that there are generally low engagement levels at various levels of employment (from safety critical workers to leadership structures).

Technology and people: If technology gets linked on the people side, then alignment becomes crucial. Alignment integrates technology and people by ensuring that the organisation has the necessary skills in place, matching new technology and skill needs, and developing skills from within. It is realised through total up-skilling cost (Stoyanova & Iliev, 2017). The advantage of up-skilling employees and ensuring alignment with technology needs is that PRASA receives immense return on investment as it will now have better skilled employees working at a higher level of productivity. This means that the work is completed faster with fewer mistakes, leading to a more profitable business. On the other hand, employees will take more pride in their work, having been made to feel important enough to invest in it. Such employees will have heightened levels of job satisfaction and confidence in what they are doing.

For PRASA to achieve its business performance through technology and innovation and mitigate railway accidents, it must strive to create a strong and positive relationship with its employees. Lee and Raschke (2016) put forward the argument that employees are motivated by jobs that challenge them and enable them to grow and learn and are demoralised by those that seem to be monotonous. Motivated employees acquire new skills; gain confidence, capability, and competence; improve their performance; and feel supported and enabled in their jobs. Through a skilled workforce, competitive products, and services as a result of new technologies can be developed, resulting in high customer experience, employee retention, investment in people, business performance and consequently boost the economy of the country.

Systems thinking: Finally, to have an agile, engaged and aligned management framework technology, innovation and people management need to be bound together by systems thinking. Systems thinking is a powerful approach in integrating all other elements of the TIPS model. It acknowledges that difficulties in problem-solving often stem from the fact that problems do not occur in isolation, but in relation to one another. This factor is already evident in the January 2022 PRASA accident, where two new trains from the modernisation programme collided one day after being commissioned (News24, 2022). From the results of the investigation, it can be inferred that an innovative solution was plugged into operations without considering other systems-related interconnections and possible causal feedback loops. In conclusion, it is important to note that for an organisation to be considered as highly competitive, all the TIPS interfaces must blend systemically and synergistically into making the organisation socially relevant.

5. Conclusions

The researcher concluded the HFM study by proposing a system-based approach model for accident prevention, taking into consideration data obtained from the study. The model is synthesised from the definition of systems thinking as espoused in the study. It is important to note that the model serves as an example which is meant to prompt a deeper enquiry into accident causation and can be adapted to add more factors which were not part of this HFM study. The researcher is of the opinion that viewing human factors using a systems approach lens will assist railway operators in mitigating accidents by managing the root causes, as well by being aware of what contributes to system equilibrium disturbance. The system can be used by a passenger railway operator such as PRASA to make note of different elements that can impact on HFM, to understand the interconnectedness of the individual elements and to understand causal loops relationships between different element to anticipate and manage all aspects of HFM in the prevention of railway accidents. The proposed system views accidents in the context of systems theory. This essentially means rail accidents do not happen in isolation; they are raised by many system factors which affect one another. In a railway traffic system, the occurrence of an accident is a result of a multitude of factors, a composite experience in which many system factors change themselves. These factors affect each other to construct a causation chain, which leads to accident occurrence (Li & Wang, 2018).

The notable aspects of the model are the recognisable interconnections and the identification and understating of synergistic relations between the elements. The system shows HFM in the middle of the model and other systemic factors that can impact its effectiveness around it. The model takes note of the micro-environment and the macro-environmental impacting th HFM. Demonstrable in model, are interconnections between HFM and other systems factors, namely governance, risk management, compliance, resource management, railway infrastructure, equipment maintenance and macro-environmental elements. The elements are interconnected to form cause-and-effect feedback loops. An example at hand is the relationship between resource management and HFM. Lack of resources in the form of financial, equipment or human resources can impact human factors in the railway system.

With fewer resources, the operator might be unable to ensure that some aspects of HFM standards are implemented, thus resulting in an accident. Conversely, if human factors are not managed appropriately, accidents can occur. The operator thereby incurs unnecessary resource implications, such as damage to property. Another example to note in the model is the relationship between the macro-environment within which the railway is functioning and HFM, which is located in the micro-environment. An example is alluded to in the secondary literature review; some accidents are caused by human errors in the manual authorisation of trains, which occur as a result of theft and vandalism of the cables.

References

Arigi, A.M., Kim, G., Park, J. & Kim, J. (2019). Human and organizational factors for multi-unit probabilistic safety assessment: Identification and characterization for the Korean case. *Nuclear Engineering and Technology,* 51(1) pp. 104-115. doi: 10.1016/j.net.2018.08.022.

Arnold, R.D. & Wade, J.P. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science*, 44 pp 669-678. doi: 10.1016/j.procs.2015.03.050.

Bouwer, D. & Hubinger, S.P. (2014). *Methods and options for preserving railway safety knowledge in a changing environment: The importance of human factors management in train operations*. Berlin: International Railway Safety Council. pp. 12-17.

Da Vinci. (2022). The Da Vinci tips managerial leadership framework: how we do it. https://www. davinci. ac.za (Accessed 23/5/2022).

Dambuza, I. (2017). An overview of the factors associated with driver distraction and inattention within the South African railway industry. *Advances in Human Aspects of Transportation*, pp. 67-75.

Department of Transport. 2015. *Transport Statistics Bulletin (Republic of South Africa)*. https://www. transport.gov.za/documents/11623/89294 (Accessed 15/10/2020).

Farndale, E. (2015). Job resources and employee engagement: A cross-national study. *Journal of Managerial Psychology*, 30(5) pp. 610-626. doi: 10.1108/JMP-09-2013-0318.

Fourie, C. & Zhuwaki, N. (2017). A modelling framework for railway infrastructure reliability analysis. *South African Journal of Industrial Engineering*, 28(4) pp. 150-160.

Fraga-Lamas, P., Fernández-Caramés, T.M. & Castedo, L. (2017). Towards the Internet of Smart Trains: A review on industrial IoT-connected railways. *Sensors (Basel, Switzerland),* 17(6) p. 1457. doi:10.3390/s17061457.

George, T.B., Mokoena, R. & Rust, F.C. (2018). A review on the current condition of rail infrastructure in South Africa. *37th Annual Southern African Transport Conference (SATC 2018).* Pretoria: Jukwaa Media. pp. 496-507.

Gill, J., Johnson, P. & Clark, M. (2010). *Research methods for managers*. Thousand Oaks, Calif.: Sage Publications.

Ginn, A. (2019). Women in rail: Industry survey. *WR Women in Rail.*

Global Railway Review Report. (2010). Innovation is important for Network Rail. *Global Railway Review*.

Hammer, M. & Vanderhaegen, F. (2014). Human factors in the railway system safety analysis process. *3rd International Rail Human Factors Conference*. pp. 1-9.

Hammerl, M. & Vanderhaegen, F. (2012). Human factors in the railway system safety analysis process. Wilson, J.R., Mills, A., Clarke, T., Rajan, J. & Dadashi, N., (Eds.), *Rail human factors around the world: impacts on and of people for successful rail operation*s. London: CRC Press. pp. 73-84. doi: 10.1201/b12742-11.

Harris, D. & Li, W. (2011). An extension of the human factors analysis and classification system for use in open systems. *Theoretical Issues in Ergonomics Science*, 12(2) pp. 108-128. doi: 10.1080/ 14639220903536559.

Hill, M. (2007). *A study of the role of human factors in railway occurrences and possible mitigation strategies.* http://tc.canada.ca/sites/default/files/migrated/humanfactors.pdf (Accessed 20/1/2020).

Huntley, R., Shai, I. & Poya, N. (2013). Regulating railway safety in an environment characterised by change. 23rd International Rail Safety Conference in Vancouver. Canada.

Hutchings, J. & Thatcher, A. (2019). A systems analysis of the South African Railway industry. In S. Bagnara, R. Tartaglia, S. Albolino, T. Alexander & Y. Fujita (Eds.) *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018).* IEA 2018. Advances in Intelligent Systems and Computing. Cham: Springer. 823 pp. 305-313. doi: 10.1007/978-3-319-96074-6_33.

Hutchings, J. (2017). *Systemic factors in the investigation of South African Railway occurrences*. Johannesburg: University of the Witwatersrand. (Thesis - PhD).

Infrasctracture news. (2018). Prasa trains most dangerous: Safety report. *Infrasctracture News,* 25 June. https://infrastructurenews.co.za/2018/06/25/prasa-trains-most-dangerous-safety-report/ (Accessed 16/8/2021).

Jidayi, Y.M. (2015). *Reliability improvement of railway infrastructure*. Stellenbosch: Stellenbosch University.

Kyriakidis, M., Majumdar, A. & Ochieng, W.Y. 2015. Data based framework to identify the most significant performance shaping factors in railway operations. *Safety Science*, 78 pp. 60-76. doi: org/10.1016/j.ssci.2015.04.010.

Kyriakidis, M., Pak, K.T. & Majumdar, A. (2015). Railway accidents caused by human error: Historic analysis of UK railways, 1945 to 2012. *Transportation Research Record. Journal of the Transportation Research Board,* 2476(1) pp. 126-136. doi:10.3141/2476-17.

Lee, M.T. & Raschke, L.R. (2016). Understanding employee motivation and organizational performance: Arguments for a set-theoretic approach. *Journal of Innovation & Knowledge*, 1(3) pp. 162-169.doi:10.1016/j.jik.2016.01.004.

Li, K. & Wang, S. (2018). A network accident causation model for monitoring railway safety. *Safety Science*, 109 pp. 398-402. doi: 10.1016/j.ssci.2018.06.008.

Mabuza, E. (2021). Fewer accidents and security incidents for SA rail in year of low traffic. *Times Live,* 21 October. https://www.timeslive.co.za/news/south-afica/2021-10-20-fewer-accidents-and-security-incidents-for-sa-rail-in-year-of low-traffic. (Accessed 14/9/2021).

Majumdar, A., Ochieng, W. & Kyriakidis, M. (2015). Data based framework to identify the most significant performance shaping factors in railway operations. *Safety science,* 78 pp. 60-76.

Makombe, G. (2017). An expose of the relationship between paradigm, method and design in research. *The Qualitative Report*, 22(12) pp. 3363-3383.

Mashoko, L. & Shivambu, R. (2015). Rail safety regulatory environment: A South African experience*. Paper presented at the 34th Annual Southern African Transport Conference, 6-9 July 2015.* "Working Together to Deliver - Sakha Sonke", CSIR International Convention Centre. Pretoria, South Africa.

Mathebula, M. & Sopazi, P. (2016). Degraded modes of operation: Antecedents for railway accidents. *Sixth SARA International Conference & Exhibition, Midrand, South Africa*.

Mukwena, M., Wessels, A. & Pretorius, J.H.C. (2019). Analysis of factors undermining the reliability of permanent way infrastructure in the South African Railway. In *Proceedings of International Conference on Industrial Engineering and Operations Management, Pilsen, Czech Republic,* July. pp. 686-697.

National Transport Master Plan 2050. (2009). Rail working group report: Rail gauge study report. RAIL GAUGE STUDY REPORT - KwaZulu-Natal Department http://www.kzntransport.gov.za › reports › natmap (Accessed 15/9/2021).

National Rail Policy. 2002. *National* Railway Safety Regulator Act 16 of 2002. www.rsr.org.za, (Accessed 14/9/2021).

National Rail Policy. (2017). *Draft Whitepaper: South African Development Community Protocol on Transport.* https://www.transport.gov.za › documents › Upda. (Accessed 9/11/ 2021).

Passenger Rail Agency of South Africa (PRASA). *African Business Journal*, 19 Juanuary. https:// www.tabj.co.za/logistics/passenger-rail-agency_of_south_africa.html (Accessed 12/2/2022).

Polit, D. & Beck, C. (2014). *Nursing research: Principles and methods*. 9th edn. Philadelphia: Lippincott Williams and Wilkins.

Railway Safety Africa. 2011. Introduction to the Railway Safety Regulator. *Railway Safety Africa,* 22 August. http://www.railwaysafrica.com/vn/2011/08/22/introduction-to-therailway-safety-regulator. (Accessed 23/5/2021).

RSR (Railway Safety Regulator). (2021). *State of Safety Report 2019/20*. RSR.

Samerei, S.A., Aghabayk, K. & Akbarzade, M.H. (2020). Underground Metro drivers: Occupational problems and job satisfaction. *Urban Rail Transit,* 6 pp. 171-184. doi:10.1007/s40864-020-00132-5.

SANS 3000-4:2011.(2011).Railway safety management-Part 4:Human factors management.Ed1.httpps://academia.edu/42115682/SANS3000_4_Human_Factors (Accessed 4/3/2019).

Senge, P. (1990). *The Fifth Discipline*, the *art and practice of the learning organization*. New York, NY: Doubleday/Currency.

Stoyanova, T. & Iliev, I. (2017). Employee engagement factor for organizational excellence. *International Journal of Business and Economic Sciences Applied Research*, 10, p. 23. dio:10.25103/ijbesar.101.03.

Sun, Li. (2018). Employee engagement: A literature review. *International Journal of Human Resource Studies*, 9(1) pp. 63-74.doi:10.5296/ijhrs.v9i1.14167.

Sweeney, L.B. & Sterman, J.D. (2000). Bathtub dynamics: Initial results of a systems thinking inventory. *System Dynamics Review*, 16(4) pp. 249-286. doi:10.1002/sdr.198.

Tidd, J. & Bessant, J. (2018). *Managing innovation: Integrating technological, market and organizational change*. 6th edn. Hoboken, NJ: Wiley.

Wang, J. (2018). *Safety theory and control technology of high-speed train operation.* London: Academic Press. doi:10.1016/C2016-0-04352-8.

Williams, C. (2009). Human error in railway operations control. *AusRAIL PLUS*, 17-19 November. Adelaide South Australia.

Wundersitz, L.N. (2019). Driver distraction and inattention in fatal and injury crashes: Findings from in-depth road crash data. *Traffic Injury Prevention,* 20(7) pp. 696-701. doi: 10.1080/15389588. 2019.1644627.