Analysis of Factors Undermining the Reliability of Permanent Way Infrastructure in the South African Railway Industry

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Abstract
Various factors have been highlighted as causes of reliability deficiency of Permanent way (Perway) infrastructure, globally. It however was not known as to which of these factors are prevalent in the South African railway industry. The study develops a framework for identifying and classifying causes of reliability deficiency of Perway. The research followed the exploratory sequential mixed methods; the researcher conducted a qualitative research in a form of structured interviews and used the results thereof to build a quantitative research survey. A quantitative questionnaire survey was used to solicit responses from 52 respondents, comprising mainly of engineers, project managers, and Technicians who possess vast experience in the management of Railway infrastructure. Findings reveal that Poor maintenance policies, strategies and implementations is the most pervasive factor causing reliability deficiency of railway Track in South Africa whilst Insufficient funding and Aging rail network became the second and third factors, respectively. The research also concluded that; Track components used in South Africa are as good as those used by other major railway organizations globally. The study recommended that; South African railway organizations should priorities the replacement of old infrastructure and as part of continuous improvements, realign and modernize their maintenance strategies and implementations.

Keywords
Railway infrastructure, Permanent way, Reliability and South Africa

1. Introduction
Rail transportation system is a key economic enabler for South Africa, fortified by its distinguished allure of environmental friendliness and capacity to haul large volumes of freight and passengers in an energy-efficient manner. It is generally understood that South Africa needs a reliable railway infrastructure to match its economic ambitions, in this increasingly competitive global economy. However, the potential for railway system to play its role in the economic development of South Africa has been largely undermined, owing to various factors such as reliability deficiency. According to the National Railway Policy Green paper, compiled by the South African National Department of Transport, the network has lost both its ability to compete with road transport in the local logistics and mobility markets, as well as its ability to support exporters in competing effectively in the global market (Department of Transport, 2015).

According to a Masters in Engineering Management Thesis published from Stellenbosch University, South African Railway transport systems has been suffering from reliability challenges due to its aging infrastructure and high utilization of its physical assets (Jidayi, 2015). This view was also expressed on a continental spectrum, by the African Development Bank, which stated that Africa runs a risk of not realizing its full potential in exploiting its abundant natural resources and wealth due to the current conditions of existing railways infrastructure and rolling stock which is poor and appalling, as a result of lack of investment in infrastructure and the absence of a supporting institutional framework (African Development Bank, 2015).
Lack of reliability of such a huge economic enabler could have dire consequences on the country’s economy and its growth prospects. Although various studies have basically identified numerous factors that may be associated with reliability deficiency, it is not known as to which of these factors are prevalent in the South African environment. This study attempts to fill this gap by developing a framework for identifying and classifying factors that cause reliability deficiency of railway track, in South Africa. The classification of the factors will be achieved using Pareto analysis which will establish the 20% of factors that could make 80% impact. The specific objectives were as follows:

- Review the available theory to identify factors that are causing reliability deficiency for various railway infrastructures
- Interview industry experts on the identified factors
- Conduct a quantitative survey within the railway industry in South Africa to test the degree of agreement on the ranking of each factor
- Compare the identified factors using Pareto analysis, to establish the priority factors

2. South Africa’s Perway Infrastructure

2.1 Sub-Headings

In South Africa, Railway transportation system was established in 1860 as a private enterprise influenced/compounded by two main drivers namely; exploitation of newly discovered mineral wealth and political victories/advent. As a colonial development, the South African Railway infrastructure was planned and developed to benefit the colonial power’s interests, and had no regard for long-term developmental needs of the colony or her people (Department of Transport, 2015). The end of the 19th century was marked by the Second Anglo-Boer War, which like any other political conflict saw the country’s Transport infrastructure, mainly the railway being damaged through sabotaged actions. The 20th century was characterized by massive industrial and economic events and the birth of democracy in 1994, which at the least meant that; the resources of the state must serve the entire synthesis of South African masses, as opposed to the previous regime (Apartheid) which was designed to only serve the minority. This new political construct came with an increased need for better and more railway infrastructure for both economic reasons as well as public services. Fast forward into the 21st century, railway industry is still addressing the inherent effects of inadequate infrastructure development and maintenance (Department of Transport, 2015).

2.2 Development of Railways in South Africa

In comparison to other railway nations, based on route kilometers, South African rail network is the eleventh largest, with a total track distance of 30 400km and 22 298 route kilometers. However, this network is mostly dominated by the Cape gauge, which is 1 067mm, also referred to as narrow gauge. The narrow gauge was found to be more suitable for South Africa’s mountainous conditions.

![Figure 1: The Structure of South African rail network](image-url)
The network depicted by the figure above is owned by various organizations in the country:

- The Passenger Rail Agency of South Africa (PRASA) which is responsible for the Metrorail commuter Services in the metropolitan areas as well as the long distance passenger rail services between the major cities, owns 2,228 km of rail network (Department of Transport, 2015).

- The Gautrain, which was built to offer international standards of public transport with high levels of speed, safety, reliability, predictability and comfort, comprises of only 80 kilometers, of which 15 km is underground.

- Most of the rail network in the country is owned by Transnet Freight Rail (TFR), a world class heavy haul freight rail company that specializes in the transportation of freight. The company maintains an extensive rail network of 31,000 track km (20,953 route kilometers) across South Africa. Their rail network connects with other rail networks in the sub-Saharan region and it represents approximately 80% of Africa's total rail infrastructure (Transnet, 2015).

2.3 Perway Infrastructure

The reliability of a railway infrastructure is a functionality of the reliability of various infrastructure subsystems. A typical railway infrastructure consists of the following subsystems:

- Telecommunications (Telecoms)
- Electricals (OHTES and Substations)
- Train Authorization Systems
- Civil Structures (Bridges, Culverts and Tunnels)
- Permanent Way (Perway), also referred to as Track

These subsystems are interconnected for the functionality of railway infrastructure, as per the figure below:

![Railway Infrastructure components](Source: Transnet)

The scope of this study was limited to the reliability of the Perway subsection of the Railway Infrastructure. Permanent way infrastructure comprises of a super structure (Track) and a sub structure (formation), as displayed by the figure below:
According to a study that sought to allocate costs for Railway Infrastructure in USA, it was established that Railway Track (Perway) and structures account for 10-50% of the Railway operating costs. The study also classified Perway as a major factor in determining the speed limits, as well as the size and weight limits for wagons and trains. Perway is so important to an extent that there are existing models used to analyses the fundamental Trade-off regarding investment in track structure and the variable cost of rail operations (Martland, 2001).

3. Literature Review
The following factors were identified as the reason why the reliability of railway track deteriorates: poor design of components and systems, Manufacturing defects and inherent flaws, Poor maintenance policies, strategies and implementations, Organizational rigidity and complexity, Human errors, Lack of critical skilled personnel, Insufficient funding, Aging rail network, Poor rail/wheel interaction management, and Excess Loads.

3.1 Poor design of components and systems
Poor design of components and system was identified as a major cause of reliability deficiency by E. Balagurusamy who stated that “poor design and incorrect manufacturing techniques are obvious reasons of the low reliability”. He further argued that manufactures of components and systems are worry of their budgets and cost of sales such that, they become hesitant to invest in improved designs and modern manufacturing techniques and technologies (Balagurusamy, 2010).

K.K Aggarwal cautioned against sophistication of systems, as part of poor design, he stated that; sophisticated systems are costly, they comprise of more components which is a risk to their own reliability and could be user unfriendly, thus increase more chances of human errors. He advised that systems should be kept as simple as they are compatible with the performance requirements (Aggarwal, 1993).

3.2 Manufacturing defects and inherent flaws
A manufacturing defect occurs when a product is being made or assembled. The two most common causes of manufacturing defects are poor-quality materials and human errors. A manufacturing defect can easily be resolved by replacing the defective products and addressing the source, as opposed to a design defect. The design process happens long before the manufacturing phase. If the involved parties fail to detect any flaw in a product’s design, such designs shall lead to a production of products with inherent defects. Design defects are not so easy to correct and could be very costly.
In most instances, the railway operators would develop specifications of the kind of products they wish to use, for suppliers to produce and supply as instructed. The railway operators are however less involved in the manufacturing of such components.

All components of the Railway Track have an expected life time, under specific working conditions. And that character would have been used to calculate the reliability of the entire system, thus a compromise to the individual components either through design or during manufacturing, shall compromise the reliability of the entire Track.

### 3.3 Poor maintenance policies, strategies and implementations

Balagurusamy agrees to Poor maintenance policies, strategies and implementations qua a major factor to the deficiency of reliability. He argued that the most important period of a system is its operating period, as such, if the organization adopt the most progressive maintenance policies and strategies, such system’s production period can actually be extended beyond the expected life cycle, thus increasing the reliability of a system. Meaning that, if the organization adopts poor maintenance policies and strategies, they might be at a risk of reducing the reliability of that particular system (Balagurusamy, 2010).

These statements are also supported by Leon Zaayman, who argues that Track design and construction should be less than 30% of the life cycle cost of the Railway Track, whilst 70% or more of the life cycle cost shall be spent on maintenance. Zaayman goes further to elaborate the importance of this factor in stating that for a railway system to be considered efficient and effective, it’s infrastructure must be reliable, available, maintainable, affordable and safe (a notion denoted as RAMAS). He believes that RAMAS can only be achieved by implementing an effective track maintenance strategy. This is a strategy based on the entire track infrastructure, track life and the entire life cycle cost of the infrastructure (Zaayman, 2016).

As per the figure below, developed by Arjen Zoeteman of the Delft University of Technology in their analysis of life cycle cost for managing rail infrastructure, it was established that not only does Maintenance strategy affect the reliability of the infrastructure but it also affects the cost of ownership and planned availability of the infrastructure (Zoeteman, 2001).

![Figure 4: Factors influencing the performance of rail infrastructure (Source: Arjen Zoeteman)](image-url)
3.4 Organizational rigidity and complexity
Organizational flexibility and organizational rigidity are common themes in strategic management. In his article, Mr. Jeremy Bradley identifies flexibility and rigidity as two common methods which describes how managers develop organizational strategies. He further warns that irrespective of the employed method, barriers are almost inevitable, hence it is advised that managers should approach strategic management holistically. He describes organizational flexibility as being amenable to adapting a company's strategies to suit varying internal and external factors that can affect its day-to-day operations whereas organizational rigidity is a management approach that is the exact opposite of flexibility. He warns that rigidity can sometimes work to the detriment of a business when managers refuse to make necessary changes (Bradley, 2017).

Balagurusamy argues that, in some organizations, rigidity of rules and procedures prohibits the creative-thinking and design. He substantiated his argument by the fact that reliability is a concern of almost all departments of an organization and as such, sufficient opportunity should be made available for all concerned personnel and management to discuss the causes of failures (Balagurusamy, 2010).

The risk of organizational rigidity may be quite high in the South African Railway sector considering that most of the railway infrastructure is owned by the state and as such managed through state-owned enterprises, which are characterized by bureaucracy, red tapes and longer lead-times

3.5 Lack of critical skilled personnel
In relation to system failures and the reliability of the system, K.K Aggarwal agrees that lack of understanding, which in most instances could be attributed to lack of skills, qualifications and experience; is a major cause to system unreliability (Aggarwal, 1993).

Railway is a very specialized industry; it requires special skills in management as well as engineering. Over and above the well recorded skills shortage in the country, Railway industry also suffers from the lack of academic support; there is no sufficient railway-specific courses offered by the existing universities and colleges in the country. In addition, the railway industry continues to lose experienced individuals into retirement which further erodes the sources of information and skills.

According to the South African Department of Higher Education and Training gazette, South Africa has three main symptoms; mismatches between qualifications and occupations, high unemployment and skills shortages (Department of Higher Education and Training, 2016).

3.6 Human errors
By definition, Human Error is simply some human output which is outside the tolerances established by the system requirements in which the person operates. Even though the rest of the world seems to be progressing towards automation, in South Africa there is a need to utilize the available labor force, as such, the Railway operators in the country have to strike a balance between automation/mechanization and the use of human resources. In one of his first major poems, Alexander Pope provided the definite truth; To err is human, meaning that human beings will always commit errors from time to time. According to K.K Aggarwal, the contribution of Human error to the unreliability may be at various stages of the life cycle of such product or system. He provided seven potential courses which human error may be attributed to: lack of understanding of the equipment, lack of understanding of the process, carelessness, forgetfulness, poor judgmental skills, absence of correct operating procedures and instructions and physical inability.

Aggarwal acknowledges that human errors may never be completely eliminated however, through proper selection and training of human resources, standardization of procedures, simplification of control schemes and other incentive measures, human errors may be drastically minimizied, thus improve the overall reliability of the system (Aggarwal, 1993).

According to a ‘Railway Accidents and Human Error’ study that was conducted describe railway accidents which involved human error occurred between 1945 and 2012 in the United Kingdom, the railway safety in UK has improved greatly with the influence of technological advancements, thus reducing the number of accidents however, it was still concluded that the number of human errors found in each accident remains more or less the same (Kam, 2013).
In South Africa there has been a series of Railway accidents that were blamed on Human errors. A preliminary investigation by the Rail Safety Regulator into a train collision accident in Elandsfontein where two trains collided, indicated that the train control officer Authorised two trains to proceed onto the same section of the track at the same time. It further indicated that the train control personnel on duty failed to observe the abnormal situation.

3.7 Insufficient funding
The African Development Bank conducted a study on Financing Policy Options for Rail Infrastructure in Africa. According to their report, rail transport market share in most countries in the continent is below 20% of the total volume of freight transport. Two major reasons for that low market share are; lack of investment in infrastructure and the absence of a supporting institutional framework (African Development Bank, 2015).

The National Rail Policy green paper, recalls the De Villiers report of 1986 which arguably contributed to the downfall of railway competitiveness. The DE Villiers report recommended that SATS should restrain from investing in the railway sector and rather focus on increasing the utilization of existent assets. The recommendation was premised on the fact that the railway sector was running at a loss and unable to compete with other modes of transport. According to the green paper, recommending an increased utilization of inherently uncompetitive assets was a compromised move (Department of Transport, 2015).

3.8 Aging rail network
The green paper blames obsolete standards and technologies that have run their course, and the subsequent failure to invest in the current generation of technologies, as the main reason for underutilized railway infrastructure (Department of Environmental Affairs, 2015). An old rail network characterized by underinvestment is intrinsically unreliable and dangerous to the community. Such a network is also characterized by high cost of ownership due to the inherent chronic failures. According to the general failure curve below, a system shall experience an increased failure rate during its worn-out stages. The majority of South Africa’s Rail network is in the worn-out stages by virtue of age:

![General failure curve](source: Indian Journal of Health Sciences)

Elsayed argued that the rapid increase in the failure rate is no longer due to random failures but the age of the system. He further recommends that such can be managed through implementation of preventative maintenance or replacement of components (Elsayed, 2012).

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1 In June 2017, two Trains collided in Elandsfontein on Gauteng’s East Rand, killing one and injuring 102 passengers. The matter was later reported as a result of signaling cable theft.

2 The study by Dr W.J. de Villiers regarding the strategic planning, management practices and systems of the South African Transport Services was published in July 1986. It was accepted in its entirety by Parliament, except for the recommendations that (i) the Minister of Transport Affairs should serve as chairman of the Control Board and (iv) that the Transport Services be exempted from company tax.
3.9 Poor rail/wheel interaction management
The international Heavy Haul Association (IHHA) and its Board of Directors commissioned guidelines to best practices for heavy haul railway operations which deals specifically with management of the wheel and rail interface. Inference is drawn from newton’s third law that when a wheel exerts a force on the rail, the rail simultaneously exerts a force of equal magnitude on the wheel and vice versa. “What is good for the railway wheel is good for the rail and vice versa” (IHHA, 2015).

Rail/wheel interaction presents a very intimate metal to metal relationship characterized by potential wear, fatigue, forces, surface shear, high and low temperature and contamination from water, lubricants, snow, leaves, etc. If this relationship is not well managed or balanced serious consequences may be experienced ranging from minor failures to derailments, which in turn could have dire implication on the rail network’s reliability.

3.10 Excess Loads
According to an article published in the Business Line, Excess loads damage the rail tracks and wheels, thus reducing the life cycle of the Track and wheels due to faster wear and tear. Apart from higher maintenance costs, this factor is even more dangerous for Rail network shared by both freight and passenger trains, since damaged rails could even result in accidents if not detected on time (Das, 2008).

The published proceedings of the third international symposium on Life-Cycle and Sustainability of Civil Infrastructure Systems, hosted Vienna, Australia in 2012 indicates that, deterioration due to corrosion and repeated overloading are the major factors when dealing with the reliability of infrastructure systems (Strauss, Frangopol, & Bergmeister, 2012).

4. Research Methodology
It was determined that this study forms part of the pragmatism research paradigm, as opposed to either Positivism or Constructivism. Pragmatism as a research paradigm arises out of actions, situations, and consequences rather than antecedent conditions (as in post-positivism). Instead of focusing on methods, pragmatic researchers emphasize the research problem and use all approaches available to understand the problem (Creswell, 2014).

As a pragmatic researcher, the author adopted mixed methods by opting to utilize both the qualitative and quantitative approaches. Qualitative and quantitative approaches represent different ends on a continuum and should not be viewed as rigid, distinct categories, polar opposites, or dichotomies. In this continuum, Mixed methods research resides in the middle since it incorporates elements of both qualitative and quantitative approaches (Newman & Benz, 1998).

Within the chosen mixed methods research approach, the researcher used the Exploratory sequential research design. Exploratory sequential research design is the one in which the researcher first conducts qualitative research, explores the views of participants, analyses the data and then uses the information to conduct a quantitative research.

In line with the chosen Exploratory sequential design, the literature review provided a theoretical basis for developing the research framework for this study. The factors undermining the reliability of railway track were identified, keeping in mind that they do not represent a complete inventory of factors causing the deficiency of track reliability but, they represent the most cited factors. Structured interviews were conducted with academic and railway experts who attended 2017 international heavy haul association (IHHA) conference held in Cape town, South Africa3. From that exercise, the researcher was introduced to

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3 In September 2017, the International Heavy Haul Association (IHHA) held their 11th conference in Cape Town, South Africa. The conference was attended by 934 delegates, from 242 different organizations and 28 countries. The conference was preceded by a technical track workshop featuring international and local railway technical experts who presented on selected topics within the Infrastructure and Rolling Stock fields.
other factors which could be of importance to this study. The factors were added before the final list of 10 variables was adopted and used for the quantitative survey.

The two-part written online questionnaire was the main instrument of data collection. Part one sought general information about the personal characteristics of respondents, such as qualification profile, level of employment in their organizations, and years of experience, amongst others. In part two, respondents were asked to rate their agreement to each of the 10 factors based on their knowledge and experience, using a scale from 1–5, where 1 = strongly disagree and 5 = strongly agree.

A total of 250 railway professionals were invited via email to participate in the on-line survey. A sum of 60 professionals responded however, 8 responses were incomplete and usable; the researcher had to discard their responses and was left with a total of 52 complete responses, representing a response rate of 87%. The target respondents were engineers, project manager, technicians and other professionals involved with railway infrastructure in South Africa.

5. Research Findings
5.1 Personal Profiles of the Respondents
Majority of the respondents (56%) were in possession of a postgraduate qualification, whereas most of the respondents were Engineers/Technologists/Specialists. The credibility of the study was also vindicated by the level of experience of the respondents; an overwhelming sum of 38% of the respondents have been in the Railway industry for more than 20 years.

5.2 Factors undermining the reliability of railway track
Respondents were asked to indicate the level of agreement to the 10 identified factors using a 5-point Likert scale where: 1 = strongly disagree, 2 = disagree, 3 = somehow agree, 4 = agree and 5 = strongly agree. Table 2 (below) details the results of this online survey.

<table>
<thead>
<tr>
<th>Unreliability Factor</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor design of components and systems</td>
<td>10</td>
<td>15</td>
<td>7</td>
<td>11</td>
<td>9</td>
<td>52</td>
</tr>
<tr>
<td>Manufacturing defects and inherent flaws</td>
<td>8</td>
<td>17</td>
<td>4</td>
<td>17</td>
<td>6</td>
<td>52</td>
</tr>
<tr>
<td>Poor maintenance policies, strategies and implementations</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>17</td>
<td>27</td>
<td>52</td>
</tr>
<tr>
<td>Organizational rigidity and complexity</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>23</td>
<td>7</td>
<td>52</td>
</tr>
<tr>
<td>Human error</td>
<td>0</td>
<td>11</td>
<td>5</td>
<td>26</td>
<td>10</td>
<td>52</td>
</tr>
<tr>
<td>Lack of critical skilled personnel</td>
<td>4</td>
<td>15</td>
<td>4</td>
<td>16</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>Aging rail network</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>19</td>
<td>23</td>
<td>52</td>
</tr>
<tr>
<td>Insufficient funding</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>17</td>
<td>26</td>
<td>52</td>
</tr>
<tr>
<td>Excess loads.</td>
<td>3</td>
<td>15</td>
<td>7</td>
<td>15</td>
<td>12</td>
<td>52</td>
</tr>
<tr>
<td>Poor rail/wheel interaction management</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>21</td>
<td>15</td>
<td>52</td>
</tr>
</tbody>
</table>

5.3 Classification of Factors
Using a weight of 1-5, were 1 represents strongly disagree and 5 represents strongly agree, a weighted score was derived for all the factors measured. The figure below depicts the weighted score per each factor:
Following the Pareto Analysis, it can be deduced that only three factors are of major impact and could be the main reasons for the demise of Track reliability in South Africa. Following the 80/20 rule, these factors are:

- Poor maintenance policies, strategies and implementations (217);
- Insufficient funding (215);
- Aging rail network (212)

Below is a depiction of the pareto diagram developed from the results of the quantitative survey:
6. Conclusions and Recommendations
Railway transportation remains a very key economic enabler for South Africa. It is of paramount importance to ensure that the reliability of the railway infrastructure remains intact and is continuously improved, to enhance railway competitiveness. This study provided a focused view of factors that are of major impact to the reliability of railway track; this will allow railway organizations to narrow their focus and channel efforts into resolving factors that will yield optimum results.

6.1 Conclusions
Following the Pareto analysis, it can be concluded that; poor design of components and systems, Manufacturing defects and inherent flaws, Organizational rigidity and complexity, application of Excess loads, Lack of Critical skills, human errors and miss management of wheel/rail interaction are not major factors undermining the reliability of railway Track in South Africa. It can therefore be deduced that:

- Railway Track components used in South Africa are as good as those used in the so called developed countries
- Overloading of trains is well managed and is of minimal impact to the reliability of railway track
- The railway organizations in the country are well managed, by properly skilled and qualified professionals
- Even though railway is losing skilled people through retirement and other reasons, the railway organizations in the country seems to be compensating for such through various training and skills development programs

It can also be concluded that, the deterioration of track reliability in South Africa is largely attributed to aging rail network, Insufficient funding as well as Poor maintenance policies, strategies and implementations.

6.2 Recommendations
Following the research findings, the following recommendations can be made:

- The railway organizations in the country should priorities the replacement of old infrastructure through capital expenditure.
- Adequate funding should be made available for railway construction, maintenance and rehabilitation projects
- As part of continuous improvements, railway organizations should realign/refocus and modernize their maintenance strategies and implementations

6.3 Future work
In line with the objective of this study, the thesis only compares the influence of various factors undermining the reliability of railway track, it does not go as further as finding solutions to quell or eradicate those factors. Future work is required to deal with the root causes of these factors as well as to find solutions to eradicate these factors for the reliability of railway track. Due to the small sample used to conduct this study, further research is highly recommended to provide a much broader view.

7. References
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8. Biographies

Mulalo Mukwena is a masters graduate from the University of Johannesburg. Mr. Mukwena holds a Bachelor of Technology in Industrial Engineering (2012) and a Master of Philosophy degree in Engineering Management (2018), both from the University of Johannesburg. He has been under the employ of a South African Railway organization for approximately eight years (since the year 2011) where he was involved closely with Railway Infrastructure management.

Arie Wessels holds a B.Sc. (Eng) (Electrical Engineering) from the University of the Witwatersrand (1968), a Cum Laude M.Ing. (Eng Management) from Rand Afrikaans University (1997) and a PhD (Eng Management) from the University of Pretoria (2013). He worked for various strategic entities in South Africa, namely; Telkom (1961 – 1986), Denel Aerospace Systems (1986 – 2002) and the University of Johannesburg (1996 until present).

Jan Harm C Pretorius obtained his BSc Hons (Electrotechnics) (1980), MIng (1982) and DIng (1997) degrees in Electrical and Electronic Engineering at the Rand Afrikaans University and an MSc (Pulse Power and Laser Physics) at the University of St Andrews in Scotland (1989), the latter cum laude. He worked at the South African Atomic Energy Corporation (AEC) as a Senior Consulting Engineer for fifteen years. He also worked as the Technology Manager at the Satellite Applications Centre (SAC) of the Council for Scientific and Industrial Research (CSIR). He is currently a Professor and Head of School: Postgraduate School of Engineering Management in the Faculty of Engineering and the Built Environment. He has co-authored more than 200 research papers and supervised over 39 PhD and 220 Master’s students in Electrical Engineering and Engineering Management. He is a registered professional engineer, professional Measurement and Verification (M&V) practitioner, senior member of the Institute of Electrical and Electronic Engineering (IEEE), fellow of the South African Institute of Electrical Engineers (SAIEE) and a fellow of the South African Academy of Engineering.