



## Defining TransNamib's Engineering Future:

A Study on the Establishment of a New Motive Power and Rolling Stock  
Repair Workshop in the Usakos -- Erongo Region of Namibia

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## Abstract

This project produced detailed preliminary designs for a locomotive and wagon repair workshop for TransNamib, the national rail company of Namibia, to be located at Usakos. We planned a more efficient layout of the infrastructure and facilities to improve upon the existing workshop in Windhoek. We developed an organogram and a machine inventory to estimate the cost of the new workshop, which will bring 133 jobs to Usakos and allow TransNamib to maintain all its fleet with great benefits for the Namibian economy.

# Executive Summary

TransNamib, the parastatal railway company in Namibia, has difficulty reliably moving freight or passengers from the port of Walvis Bay to the rest of its network. Many of TransNamib's locomotives and rolling stock are in need of repair. The only workshop for heavy repairs is in Windhoek, the capital. Though centrally located in the administrative centre of Namibia, the repair shop is a significant distance from Walvis Bay and from the main train route extending towards the Angolan border. Most break-downs occur near Walvis Bay or along that line. Consequently, TransNamib must bring trains requiring repairs to Windhoek -- and even outsourced them to South Africa -- a costly process that requires additional time and resources. TransNamib also has purchased newer locomotives from General Electric that the existing repair shop in Windhoek is not equipped to maintain.

TransNamib controls the property of an abandoned repair workshop in the town of Usakos, a community located between Windhoek and Walvis Bay. The company's strained repair system has led them to look into establishing a modern repair workshop in the town of Usakos, which is ideal for the project since it is near the junction of Namibia's most active rail lines, which is why the town was originally established. An efficient and modern repair workshop in Usakos could service the new locomotives as well as the older rolling stock. The town of Usakos suffers from high unemployment, and a new repair workshop could provide a substantial economic benefit to the citizens of Usakos, to TransNamib, and to Namibia as a whole.

The mission of this project was to develop a preliminary design and layout for this new repair workshop at Usakos to assist TransNamib with its plans. This project had two main objectives.

The first objective was to garner an understanding of the technology and processes for the Windhoek repair shop and understand what is required in a TransNamib workshop. This was accomplished by making observations and interviewing the supervisors of the Windhoek repair shop. Through these interviews we discovered that the main issues stemmed from old machinery and technology, lack of skilled manpower, and insufficient parts to complete repairs. The information gained through the interviews and observations provided the basis for the new design and improvements for the repair workshop in Usakos.

The second objective was to develop a detailed preliminary design for new Usakos repair shop. The new shop was designed with the purpose of creating a modern and efficient workshop. One of our design goals was to combine locomotive and rolling stock repair sections together. In order to begin the design we went to Usakos to assess the structures there, determine the area boundaries, and speak with members of the city council. From our observations, we determined that four existing buildings in the area are suitable to be re-utilized in our designs. The largest remaining structure will be used for the wagon repair area. The rest of the workshop has been designed around this structure, with buildings for repairs, platform maintenance and daily inspections.

The secondary buildings were placed in the northern section of the design area. These buildings include offices for senior engineers and management staff, along with ablutions and a canteen building for workers and a training centre. The design can be seen in Figure 0.1.



Figure 0.1 - Final Design

The full internal design is given in Figure 0.2 below. Inside the workshop, two main sections were established for heavy and light repairs. This layout allows for different sized cranes to be utilized and minimizes the needed movement of a locomotive to be repaired. The heavy repair workshop is responsible for full disassembly of locomotives and movement of the engines and wheels. Having a wheel repair section between locomotive and wagon areas allows quick access for both the wagon and locomotive workshops. This is a significant improvement over the Windhoek shop, which had the two sections 120 meters apart from each other. The rest of the heavy repair sections were relocated to maximize the efficiency and lessen the distance to be travelled by crane. The light repair section was built to allow free movement between it and the maintenance platforms. This allows for cranes to carry components from locomotives under maintenance to their respective sub-shops. These shops were then re-organized to ensure they are located next to important ardrex baths for cleaning or required machine shops.

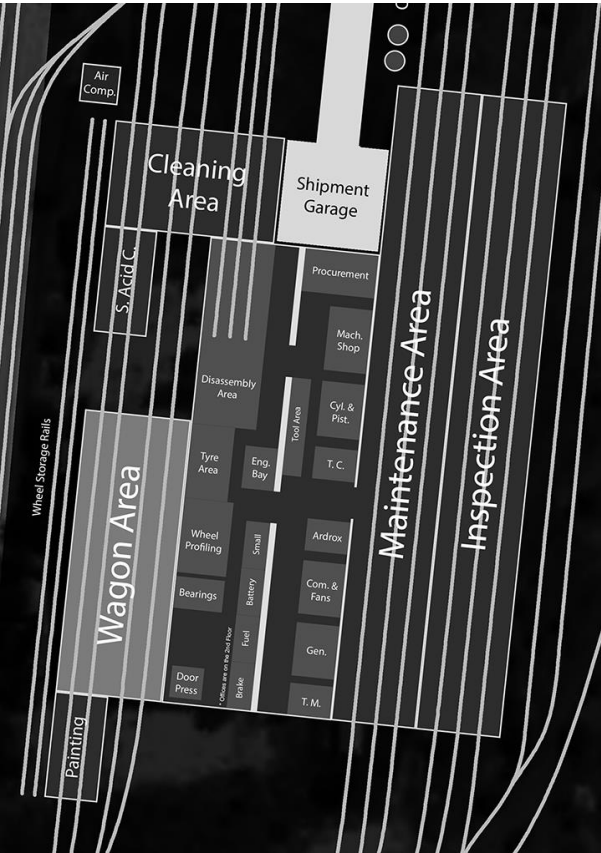


Figure 0.2 - Interior Design

In addition, we made a modernized machinery inventory for the new shop. The information on machinery at the Windhoek repair shop displayed multiple gaps in the repair process due to out-of-date or inoperative machines. These gaps were filled by adding modernized versions of required machines to the inventory to allow for faster repairs. New machines were also investigated for the shop based on specific requests from technical supervisors in Windhoek. This complete inventory of 47 machine systems will allow TransNamib to keep repairs in-house and complete them more efficiently.





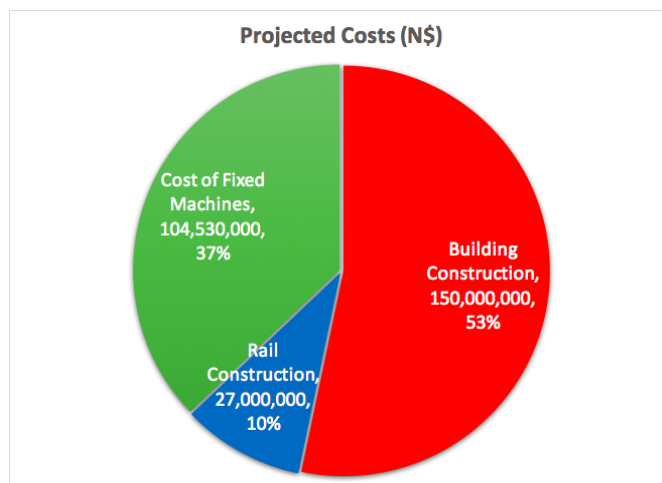


Figure 0.4 - Final Cost Breakdown

This new shop represents a large investment, but it could also provide a multitude of benefits for TransNamib and the country of Namibia. The town of Usakos was built because of its importance to rail during the era of steam trains. When the fleet was upgraded to diesel electric in 1960, the shop in Usakos quickly became obsolete. Once the shop shut down, the city began to degrade. Today the unemployment in Usakos is in the range of 40-60% for a total population of just over 3000. The staffing of this new repair shop will **create 133 new jobs** and a training centre will give workers the opportunity to learn valuable trade skills. Rail is what made Usakos a notable city in the beginning of 20th century, and the revival of its workshop would allow the city to return to its status as a rail hub and thrive again in the 21st century.

The new shop in Usakos is additionally meant to work in tandem with the current workshop in Windhoek. Our improvements to the workshop's structure and layout allow TransNamib to more than **double its repair capabilities**. The workshop in Usakos was designed to be a modern and efficient workshop and improve on the gaps in Windhoek. Moving the majority locomotive and wagon repairs to this new workshop will offer benefits to TransNamib. This modern workshop design will allow TransNamib to complete repairs quickly and completely. This will result in less locomotives being stabled at a time. This allows more trains and therefore cargo to be transported at a time. This increased rate of transport will allow for higher profits for the company.

A new repair shop in Usakos also creates the opportunity to improve the Windhoek repair workshop. Currently, the Windhoek shop cannot be closed even briefly for updates, as this would halt repair and maintenance for all of TransNamib's fleet. TransNamib also has plans to incorporate a new commuter rail into Windhoek which would be used to transport workers who live outside the city into Windhoek. The facility in Windhoek could be adapted to serve those plans.

This study indicates that the establishment of a modern workshop in Usakos can greatly benefit TransNamib, Usakos and the country of Namibia. We strongly recommend that the plans for this revival move forward in order to keep TransNamib's repair process current and effective.

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## Glossary

Locomotive	-	Provides motive power contains engine and other complex components
Wagon	-	Attachments to locomotive used to hold bulk resources such as wheat, coal, petrol, etc.
Carriages	-	Attachments to locomotive used to carry people
Rolling stock	-	Refers to carriages and wagons
Train	-	Combination of locomotive, and carriages or wagons
Bogie (chassis)	-	Under section of a locomotive where, traction motor, wheels and brakes are contained
Shunting	-	Process of moving locomotives and wagons around the workshop
Stabled	-	Term for in-operational locomotives at a repair workshop
Ardrox	-	Acid bath in shop
Ablution	-	Area that contains locker rooms, bathrooms and showers
Effluent plant	-	Plant for cleaning of contaminated water

## Authorship

Throughout the completion of the project, the responsibilities were shared equally between all three group members. Each section of the paper was repetitively written and edited by each group member. Individual group members were in charge of sections of the paper, but fellow group members helped to edit and contribute to the sections. Every diagram created was collaboratively designed before one group member completed the final design steps. We believe the collaborative nature of our group contributed to the success of this project.

## Acknowledgments

We would like to thank everyone at TransNamib that helped us to make this project a reality. Specifically, we would like to thank our head sponsor, Kunetsa Kufakowadya along with Gabes Nghipukuula, Reggie du Toit, Daniel David and Simon Amutenya. A special thank you to Wilhelm Saltpeter and Joe van Zyl and the technical supervisors at the Windhoek workshop for hosting us at the workshops and answering any and all questions we had. Thank you to our two academic advisors Fabio Carrera and Peter Hansen for helping us along the process of preparing this report along with our preparatory term advisor Anna Jaysane-Darr.

# 1 Introduction

Since the first rail lines were built in South West Africa by German colonists to transport heavy copper ore, trains have played an important role in the history, economics and social life of Namibia. Expanded by South Africa, the rail network has quickly turned into the main transportation hub for heavy transport, taking cargo from Walvis Bay into neighbouring regions in Southern Africa. The key to Namibia's future success is to leverage this regional cooperation, trade and transportation. With the right investments, the rail network of Namibia has the power to make Namibia a key player in the economy of southern Africa.

Today, TransNamib, the parastatal railway company in Namibia, has difficulty reliably moving freight or passengers from Walvis Bay to the other parts of its network. TransNamib's fleet is understocked, which means the number of functional locomotives and wagons does not match the current demand. According to Chief Executive Hippy Tjivikua, TransNamib requires 15 trains a day to meet its demands, with 27 operating a day being the ideal. However, as of January 2015, TransNamib operates about 15 trains a week (Ash, 2015), due to an inadequately equipped repair workshop, along with the aging rolling stock.

The only workshop for heavy repairs is at the TransNamib Repair Workshop in Windhoek, the capital of Namibia. Even though the city is centrally located and the administrative centre for the country as a whole, this repair shop is a significant distance from Walvis Bay and the main train route extending towards the Angolan border. Consequently, TransNamib must transport trains requiring repairs to Windhoek--and even to South Africa--a costly process that requires additional time and resources. In addition, the Windhoek shop is not fully equipped to maintain the locomotives and wagons of TransNamib. There are repairs that cannot be done in Windhoek, which are sent to South Africa. If a locomotive stops working, there is limited infrastructure to return it to service in Namibia.

The current rolling stock of TransNamib is also prone to problems due to its age. 32 of TransNamib's 50 active locomotives have been in service for over 50 years (South African Class 33-400). To remedy this situation, TransNamib purchased 18 Chinese locomotives that, due to a combination of design faults and an expensive repair process, had to be taken out of service after only a few years of operation (Grobler, 2012). More recently, TransNamib has purchased newer locomotives from General Electric; however, the existing repair shop in Windhoek is not equipped to maintain and repair these new GE locomotives.

Working with TransNamib, our team examined the possibility of erecting a new repair shop in Usakos, a town in the Erongo region, located closer to Walvis Bay and at the junction of the most active train lines. An efficient and modern shop at this location could repair the new locomotives and rolling stock, and would be more centrally located in the TransNamib rail

network. The mission of this project is to aid TransNamib in the conceptual design and layout of this new repair workshop at Usakos.

This project had two main objectives. The first objective was to determine the technology and processes for the Windhoek repair shop, we talked with supervisors of each repair area to identify the workflow of repairs in their section and all the machines required for proper repairs. The second objective was to design the layout of the new Usakos repair shop. We went to Usakos to analyse the available infrastructure. We created designs based on aerial maps of Usakos. Along with the designs, an inventory of required machines was created. An organogram of a staffing hierarchy was then created for this new workshop. The possible costs of these designs, machines and staffing were calculated. A new workshop will enable TransNamib to complete the maintenance and repair of their rolling stock and motive power, increase profits and have a significant impact on the nation's economy.



## 2 Background

Reviving a train maintenance workshop is a complex process with many factors to take into account. The economic strength of Namibia and the role of rail transport in the economy were the starting point for our research. This chapter provides background research on the economy of Namibia, TransNamib, and current train operations and maintenance techniques.

### 2.1 Economy of Namibia

Namibia has a prospering economy. The rich natural reserves provide a good opportunity to establish mining, manufacturing and mineral enrichment sectors. The main challenge that Namibia faces today is to renovate the infrastructure fast enough so that it would support the emerging sectors in terms of development. This limits the ability to achieve stable economic growth, and leads to the highest poverty gap in the world. On a scale created to measuring inequality around the world, Namibia has a record 0.74 GINI coefficient (UN World Report, 2013). As a result, the country experiences an unemployment rate of 28% and a limited growth in their US\$12 bn nominal GDP (World Bank, 2013). To address this issue, Namibia invests significantly in reviving its infrastructure, in part through TransNamib's rolling stock renovations.

The main production areas in Namibia are industry (33% of GDP), manufacturing (12%) and agriculture (7%). While the agricultural sector is shrinking by an average of 7% per year, manufacturing and industry, mainly the mining sector, are growing at a significant pace (World Bank, 2013). These are good indicators of investments in development and has a positive effect on the economic growth of the country. The main source of the manufacturing sector is copper, as the country both mines and purifies copper. The mining sector is focused more on uranium, and Namibia was the 5th largest producer worldwide of uranium in 2015 (World Nuclear Association, 2015). Both of these resources are heavy in weight, which requires a rail network for transportation. Unfortunately, TransNamib cannot meet this demand, due to the undersupply of rolling stock and locomotives. This increases the costs of transportation and creates a limiting factor in production.

Many of the goods produced in Namibia are traded with other countries. The main exports of the country by value are uranium, copper, and diamonds (Our-Africa, 2014). There is also a recent discovery of natural gas and petroleum in Orange Basin, which is expected to have a significant contribution to the country's exports in the next two years (Oil & Gas Technology, 2014). The rest of the goods are imported into the country. The main imports of Namibia are building materials, manufacturing materials and agricultural products. Most of this trade occurs with Angola, Botswana, Zambia and South Africa, and since both the imports and exports are heavy goods, they are transported through rail. Having both imports and exports use the same infrastructure leads to competition, which results in a shift towards imports due to their critical

nature. The net balance of Namibian trade is US\$1.2 bn loss from US\$6.3 bn exports and US\$7.5 bn imports (CIA World Factbook, 2014).

Even though trade plays a crucial role in Namibian economy, the biggest means of trade, rail lines, need urgent improvement. Since the first rail lines were established, the infrastructure has seen very few changes and renovations. Trains still run on railways built for steam trains, and the most of the old maintenance infrastructure is not operational today. The process of running recently acquired, relatively new technology trains on old infrastructure, especially railways, introduces further problems, and increases the likelihood of breakdowns.

The first rail line built by Germans in 1897 was created to connect the coastal city Swakopmund to the capital Windhoek. Named “Statsbahn,” the purpose of this line was to establish a trade route to the largest city of Namibia, and prepare a main transportation hub to reach out to the mining areas that mostly lie in the northern region of the country. From 1902 to 1908, hundreds of kilometres of railroad were established to connect social and economic centres of the Namibia to the central rail hub. (Direks, Klaus, 2007) Walvis Bay was added to the transportation hub in 1914. After World War I, South Africa took over Namibia and its railways. This introduced a unified railway system in Southern Africa and increased the importance of Walvis Bay in African trade. The rail lines have continued to expand and now the lines allow for trade to reach most of the country, as the map of the current rail lines is given below in Figure 2.1.



Figure 2.1 - TransNamib Rail Map (2013 Annual Report, 2014)

## 2.2 TransNamib and Namibian Railways

TransNamib is the largest company that manages the rolling stock of Namibia. It was established in 1994 as a government organization to control rail transport for the newly independent country. It was reorganized in 2002 as a parastatal entity, which is government-owned but is operated as a private company, responsible for managing its own budget. TransNamib’s last reported budget for the 2012/2013 fiscal year, shows losses of around N\$194m (2013 Annual Report, 2014). These losses were reported from 2011-2013, and therefore the company is looking for methods to improve the repair process and cut costs.

Through the transportation of bulk freight, TransNamib makes a significant contribution to the Namibian economy, and its estimated N\$198bn (US\$12.3bn) GDP (World Bank, 2014). Most of this cargo is transported between the capital city of Windhoek, Walvis Bay, and the north of Namibia into Angola. This line is generally in good condition (see Figure 2.1) which allows heavy freight cargo transportation and it is extensively used by sub-Saharan African countries for transatlantic trade. The cargo arriving at the port of Walvis Bay is carried inland by TransNamib to Angola, Botswana, and South Africa. This provides a significant trade advantage to Namibia and further supports the growth of the TransNamib company.

The main resources carried by tonnage are bulk liquids (34%), mining resources (33%), building materials (12%) and containers (12%) as shown in Figure 2.2 below (2013 Annual Report, 2014).

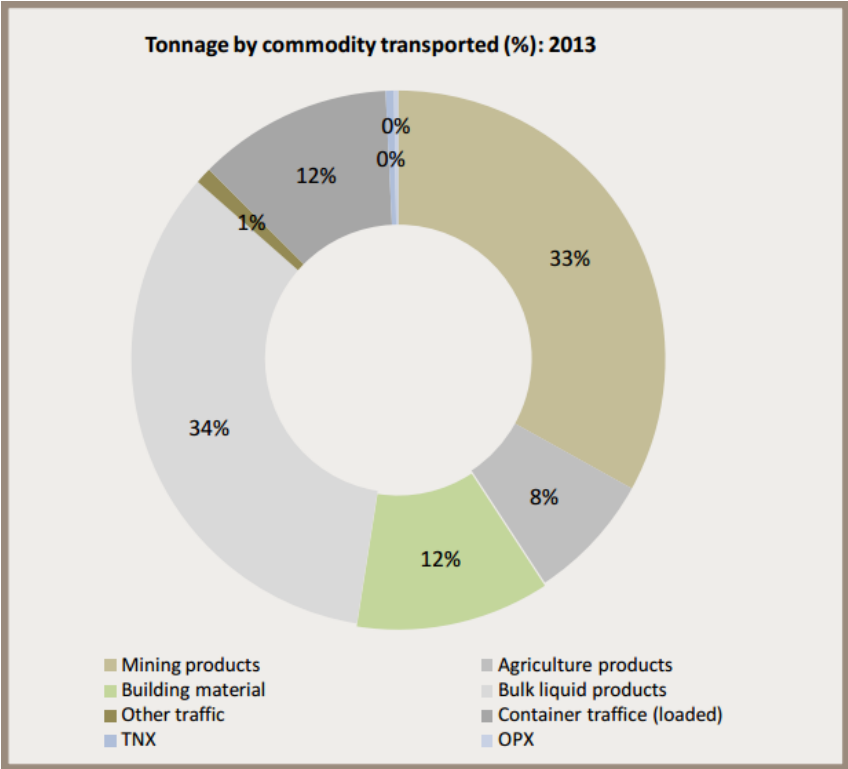


Figure 2.2 - TransNamib 2013 Transported Commodity Tonnages

Some of the main costs of transporting these natural resources come from operation of the trains. As the tonnage of the weight increases, the likeliness of repairs and operational costs also increase.

TransNamib currently has a fleet of 1604 wagons, 37 passenger coaches, and 50 active locomotives to carry this freight (TransNamibWebsite, 2016). Most locomotives that TransNamib uses are second-hand General Electric (GE) locomotives from South Africa. Thirty-three of the fifty trains in service are the South African class 33-400, otherwise known as the GE U20C (South African Class 33-400), while four are the slightly older GE U20C1 although all of them are currently stabled. These electric-diesel locomotives were put into service in South Africa from 1966 to 1968, and once Namibia gained independence in 1990, they were transferred to TransNamib.

Due to the fact that these trains are over 40 years old, TransNamib has to carry out continuous refurbishment programs to maintain them (2013 Annual Report, 2014). Even though they are dated, these locomotives are still the most reliable ones TransNamib has in its fleet. TransNamib purchased 18 locomotives from China in recent years, but they have broken down quickly and TransNamib lacks the necessary parts to repair them. Thus, several of the Chinese trains have been scrapped for parts completely (Poolman, 2012).

### 2.3 Train Accidents and Repairs in Namibia

TransNamib has a history of breakdowns and maintenance problems in its rolling stock. In 2013 alone there were a total of 190 accidents. 133 accidents occurred within the yard, while 23 happened on the main line and 34 at level crossings (2013 Annual Report p.20). The majority of accidents that occur in the yard are simple to address, due to their proximity to the shop. However, there are much more severe accidents that occur on mainlines. There were two major accidents that happened in 2013: The Dune Seven crash and the Arandis derailment.

The Dune Seven Crash occurred when a truck stopped on the tracks and caused a crash spanning over 70 meters of rail. The crash removed 2 locomotives and 17 wagons from the active fleet (Reporter 2, 2012). The cost of the Dune Seven crash alone was about N\$65 million (2013 Annual Report, 2014, p.12). The Arandis derailment also caused dramatic problems as the entire train line from Walvis Bay to Windhoek was shut down for four days due to the severity of the crash and damage to the rails. The crash cost the life of one conductor along with damage of two locomotives and 35 wagons. This accident ended up costing the company around N\$120 million (Brake Failure, 2013).

From 2013 to the start of 2015 there was a total of 46 reported accidents on mainlines the majority of the accidents occurred in Walvis Bay and on the continuation of that line leading north to Tsumeb. This can be seen as a direct result of the increased train traffic on this line compared to other locations in Namibia. The locations of these accidents is represented in Figure 2.3.

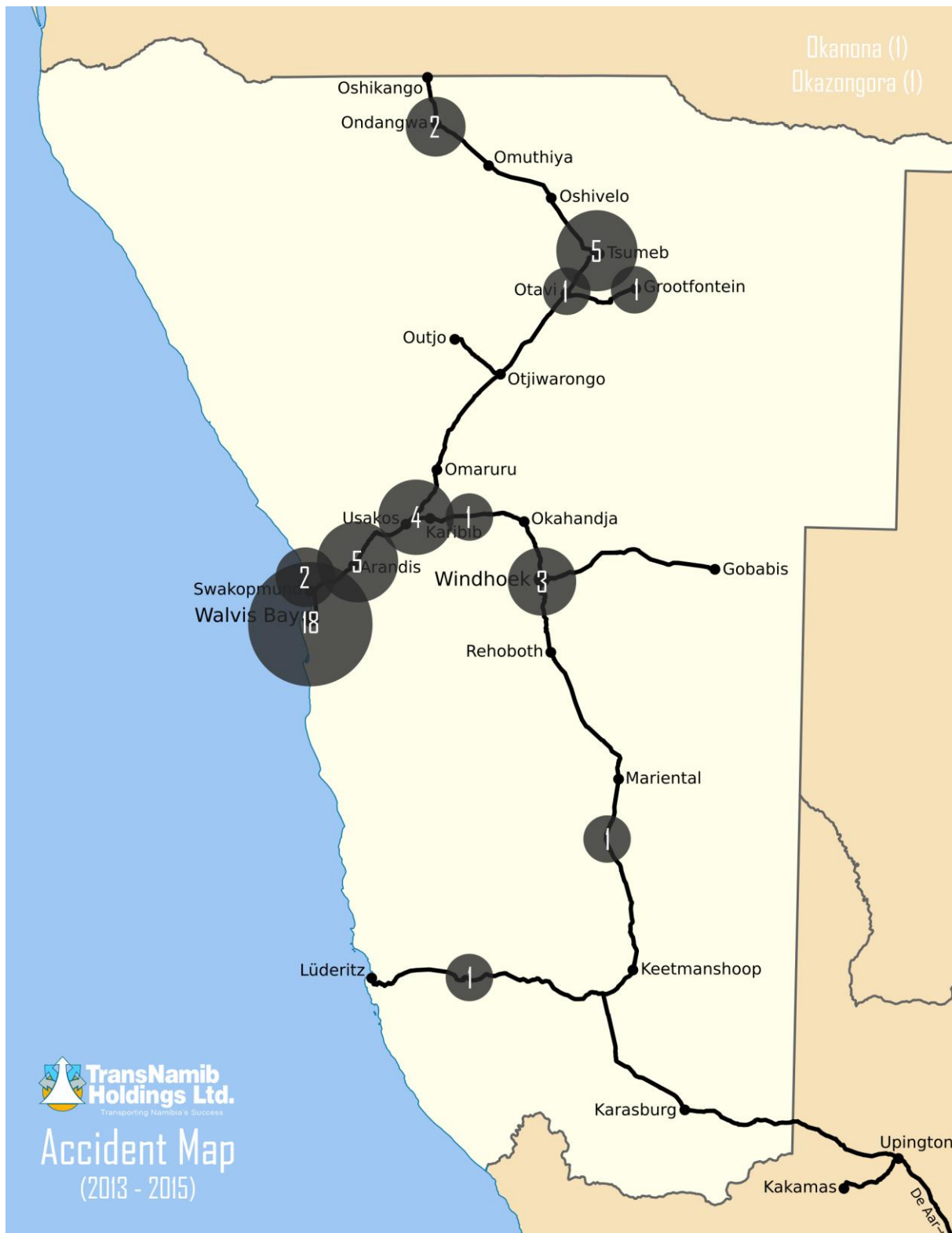


Figure 2.3 - 2013-2015 Train Accident map

### 2.3.1 Rolling Stock Repair and Maintenance

Even though these large accidents cost TransNamib a significant amount of money, the work done in the repair shops consists of mainly regular rolling stock and locomotive repairs. These repairs are focused on regular maintenance and replacement of worn parts.

Wagons must be regularly maintained and repaired after approximately 5-8 years. The metal vehicles can become rusted and deformed over time and must be refitted and cleaned in the maintenance shed. The repair process varies depending on the type of wagon that arrives for repair. When a wagon arrives in the repair shop, it is sandblasted and steam cleaned in order to properly evaluate any damages it may have incurred. Its individual parts, specifically the wheels, brakes and axles are evaluated for corrosion or serious damage. These parts can then be repaired or replaced before reassembling and testing of the vehicle's brakes (A Draft Performance, 2011). Rolling stock and motive power wheels function with metal tyres to help maintain traction and protect the axle. The wheels and tyres are the main focus throughout the repair process since degradation in the tyres or flange angles can have a serious effect on wheel performance.

Once a problem is identified, wheels then need to be either removed from the vehicle or fixed while on the vehicle (Palo, 2013). A device called an *underfloor wheel lathe* can be used to re-profile and realign worn down tyres without disassembling the entire wagon (Connor, 2016). This practice has become increasingly common due to the costliness of disassembling a wagon or locomotive (Palo, 2013). Overall, rolling stock repairs are a simpler and less expensive than locomotive repairs.

### 2.3.2 Locomotive Maintenance and Repair

Locomotives act as the source of motive power for a train. They are powered by a combination of a diesel engine and an electrical generator. Locomotives are diesel electric to eliminate the need for a transmission and gearbox for the engine that would require at least thirty gears (Karim, 2001). The diesel electric engine has its power supplemented by a turbocharger. A turbocharger is a device that allows for more air to be pumped into the cylinders by taking the exhaust air and recycling it back. The engine uses the fuel to power everything inside the locomotive from the generators (alternators), to the radiator fan and air compressor. Compressors are used to stop the locomotive since the brakes use an air system to slow down. The generator turns the mechanical energy into electrical energy that is then used to power the traction motors on the locomotive. These motors are what actually move the train as they spin the wheels and propel the locomotive forward. The radiator fan powered by the drive shaft of the engine cools the water in the radiator and keeps the locomotive from overheating while running. The air compressor works to make sure the hydraulic brakes have power when needed (Connors).

Repairs of locomotives can be a complicated and costly process due to the complex electronics and engine systems involved. The systems are highlighted in the picture in Figure 2.4.

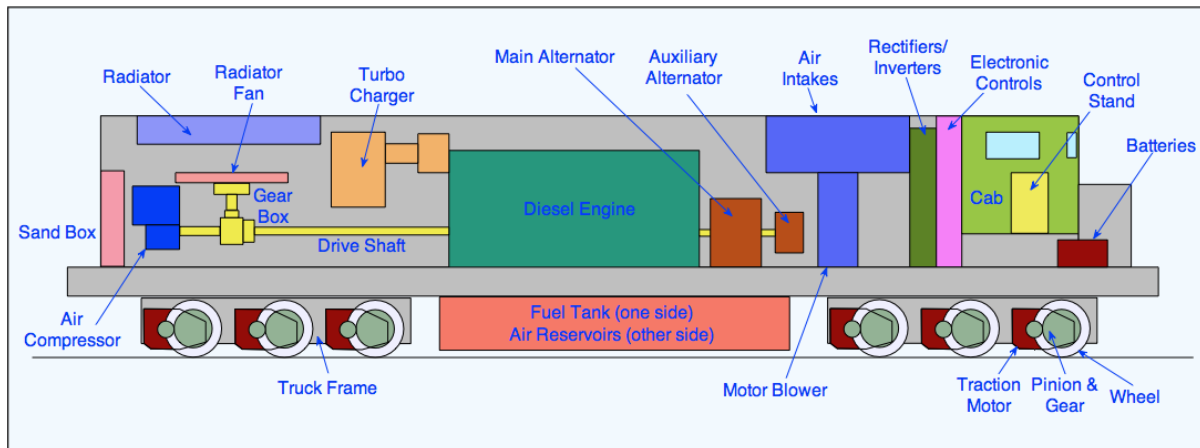


Figure 2.4 - Anatomy of a Diesel Electric Locomotive (Connors)

Similar to rolling stock, locomotives undergo a process of cleaning and inspection, followed by disassembly and repairs, before being reassembled and tested. Different levels of maintenance and inspection must take place depending on the specific service schedule and age of the vehicle. A service schedule for train inspections is used, increasing from monthly, three monthly, six monthly and annual services (TransNamib Records).

The main systems that are focused on during locomotive repair include the engine, radiator, fuel pumps, the electrical control systems and wiring, and the condition of the “bogies” or chassis (refer to Figure 2.4 above). Each system must then be reviewed for a multitude of possible problems. These reviews involve the above and below deck platforms to analyse different sections of the locomotives (Connor, 2016). The engines commonly require work, with pistons and cylinders being removed and replaced directly from the engine block. The replacement is due to the fact that the piston is continually pumping through the cylinder; this causes wear over time, and more petrol for the engine to work at the same rate causing of efficiency. After eight years, the cylinder needs to be fully replaced before it can be returned to the engine. The pistons and cylinder casings are longer lasting.

The wheels are also reviewed and maintained in a similar manner to the rolling stock wheels, with an underfloor lathe being more common due to the size and weight of modern locomotives (Palo, 2013). The complexity and scale of these repairs and inspections can result in lapses in proper locomotive care.



## 2.4 Project Goals and Organization of the Report

The main goal of our project is to aid TransNamib in developing the most efficient design for a new repair workshop in the town of Usakos. This project will allow TransNamib to erect a new repair shop to maintain their current and future rolling stock and locomotives along with completing all repairs in house. Our team has created two main components in order to properly complete this goal, as listed below:

1. To Identify Operational Procedures and Technologies of a TransNamib repair shop
2. To Design an Operational Workshop Layout for the Usakos Repair Shop along with the staffing and cost of the new workshop

Our group worked to prepare a complete report that would allow TransNamib to quickly move forward with the revival of this workshop. This final product contains a structural layout and outline for the cost of the shop furnished with the desired technologies from TransNamib. This shop design, along with an analysis of possible costs and savings will aid in the creation of a formal government proposal in the future. The report is organized around these two objectives. The first will detail the operations of the current TransNamib repair shop in Windhoek. The second presents the conceptual design, staffing, and equipment required to build a new repair workshop in Usakos.

## 3 Windhoek Repair Workshop

The Windhoek repair workshop is located in North Windhoek, at the northern-most section of TransNamib's land in the centre of the city. The shop opened in 1960 and has been the main source of repairs and maintenance for TransNamib since then.

Very little has changed about the shop since its original construction, yet it still carries out a regular schedule of repairs and maintenance. It is currently the oldest functioning diesel electric workshop in Southern Africa. The locomotive workshop completes 30-35 scheduled maintenances a month, and in 2012-2013 the carriage and wagon workshop performed 813 scheduled and 2,330 unscheduled services on rolling stock along with 14 heavy rolling stock repairs. This shop also sandblasted and painted 67 rolling stock and even repaired 93 grain carrying rolling stock for Namib Mills, a local milling company (2013 Annual Report, 2014). TransNamib locomotives are shipped here from across the country for repairs.

While still completing a significant number of repairs, the Windhoek repair workshop is unable to repair some damaged pieces of rolling stock. Therefore, TransNamib outsources many of its more intense repairs to outside companies, such as African Rail and Traction Services, Rolling Stock Repairs, and Transnet Engineering. For example, in 2013, 14 heavy repairs of rolling stock were done in-house, while 19 were completed by Rolling Stock Repairs and no locomotive repairs were reported (TransNamib Annual Report, 2013).

In 2012, five locomotive repairs were completed, three by Transnet Rail Engineering and two by African Rail and Traction Services (TransNamib Annual Report, 2012). Rolling Stock Repairs is a repair company based in Windhoek that has done heavy repairs of both rolling stock and locomotives for TransNamib. African Rail and Traction Services is a large locomotive repair company based in South Africa that carries out major repairs on multiple types of locomotives for companies throughout Southern Africa (African Rail and Traction Services, 2010). This company has completed accident repairs and refurbishments on TransNamib locomotives.

As stated previously, many TransNamib locomotives came from South Africa, therefore multiple locomotives have been sent to Transnet for repairs in recent years. While locomotives will be sent away for repairs, it is even more common for TransNamib to send away different parts and components for outside work. This is due to the shop's inability to fully overhaul these parts in-house. This common outsourcing to Transnet shows the gap in TransNamib abilities to repair and maintain their current rolling stock.

### 3.1 Structure of the Workshop

The repair workshop is situated 3 kilometres outside of central Windhoek. There are rail lines coming to the workshop from Windhoek train station (south) and extending along the B1

road (north). There are various other areas around the workshop operated by different divisions of TransNamib such as rail repairs and a marshalling yard. The Windhoek Repair Workshop drawings can be seen below in Figure 3.1

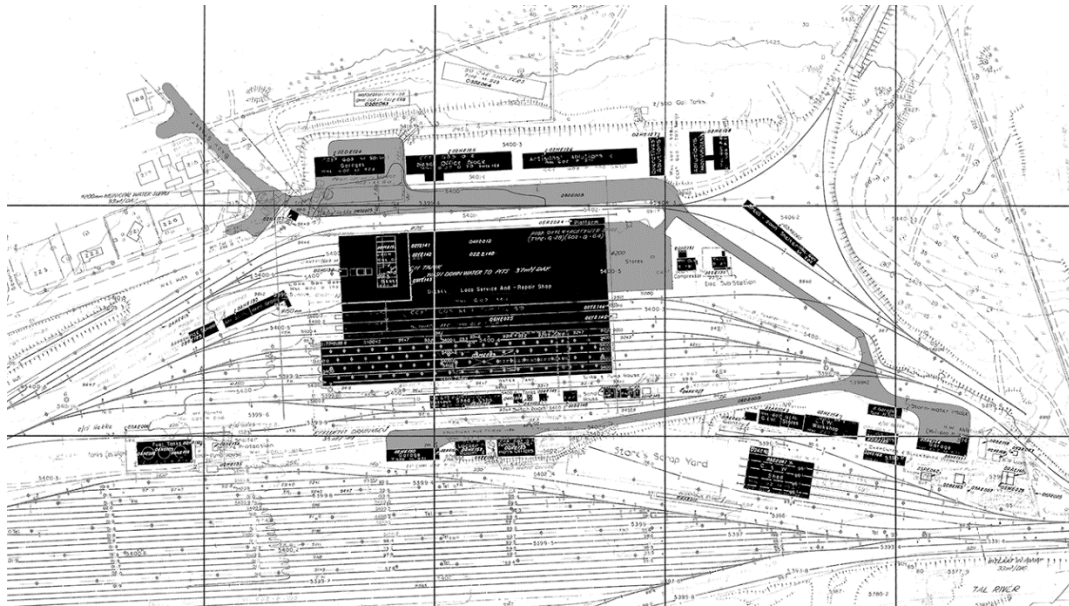


Figure 3.1 - Windhoek Repair Workshop

The repair workshop is divided into two different shops, one responsible for locomotive repairs and their required daily inspections and maintenance. The locomotive section can be seen below in Figure 3.2. The wagon section can be seen in Figure 3.3 and is responsible for rolling stock maintenance and repairs.



Figure 3.2 - Locomotive Repair Section

The locomotive workshop has two main buildings, one for heavy repairs and disassembly and the other for running repairs that can be completed without disassembly. The heavy repairs building is divided into 5 different sections; cleaning, wheel maintenance, engine maintenance,

electrical maintenance and running maintenance. The running repairs building consists of 3 platform tracks with room for 6 trains on each track. These tracks are built to allow for maintenance work above and below the locomotives.

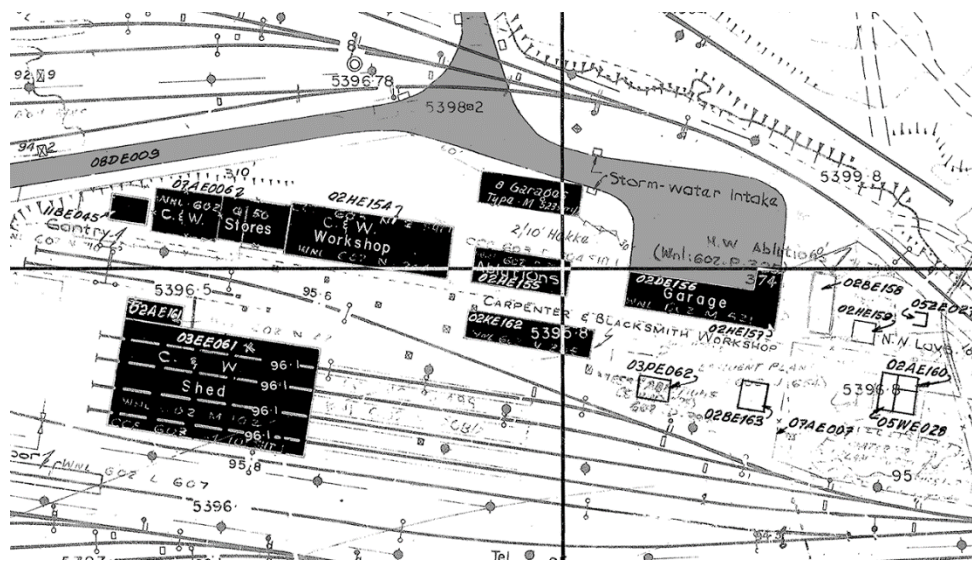


Figure 3.3 - Rolling Stock Repair Area

The rolling stock workshop is separate from the locomotive workshop, and is composed of multiple semi-open sheet metal canopies. Here, all maintenance and cleaning of the rolling stock is completed. Attached to the rolling stock repair area is a track for sandblasting and painting of the rolling stock.

We evaluated the repair processes currently employed at the Windhoek repair shop to identify what processes and systems are most important for repairing and maintaining the rolling stock. The level of machine quality in the shop and its current layout for rolling stock maintenance and repair gave us an understanding of the basic components required for a TransNamib shop.

These evaluations were completed by visiting the current repair workshop in Windhoek. Here, through detailed inspection and tours by the resident technical supervisors, we created an inventory of all the machines and mechanical systems currently required for maintenance of the company's rolling stock to standardize the process, we followed the parameters outlined in Appendix C. Through interviews and observations, we were able to understand the workflow and processes for each section of the workshop. Since outsourcing of major repair jobs is common for TransNamib, questions centred on exactly what kind of repairs are being outsourced so that the current gap in repairs can be addressed. This information was mainly extracted from interviews and conversations with the shop supervisors, along with reviewing the maintenance checklists and by on-site observations. All of our findings were later taken into account to design the new repair workshop in Usakos, to cater to the needs of TransNamib.

### 3.2 Locomotive Repair and Maintenance

Through our time at the repair workshop we identified the different repair areas that make up the locomotive workshop, which is divided into: wheel repairs (Section W), cleaning (C), engine repairs (D), electrical repairs (E), and running repairs and inspections (R and I). A diagram of the layout can be seen below in Figure 3.4

Each of these sub-shops contains special machinery and equipment unique to repairs for part of the locomotive. There are additional areas outside the repair workshop that are necessary for the shop. These include office areas where the managers and supervisors can work along with warehouses for storage of spare rolling stock and locomotives. There are also areas allotted for the devices that provide power, water and compressed air to the entire repair Workshop.

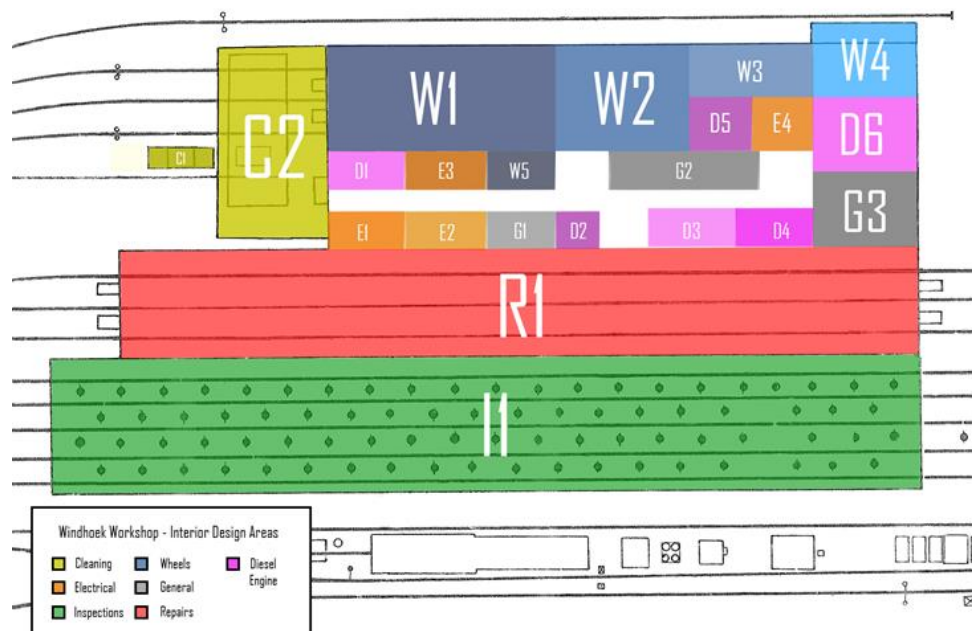


Figure 3.4 - Locomotive Repair Area Layout

#### 3.2.1 Wheel Repairs (W)

The main work happens in heavy repairs section of the Windhoek repair shop. There are two main areas, the locomotive disassembly area (W1) and the wheel re-profiling area (W2). When a locomotive comes for heavy repairs, it enters the shop in the disassembly area. Here, with the help of three 30 ton cranes, the locomotives are lifted off from bogies. There are three sets of traction motors and wheels per bogie, which are then separated. After steam cleaning to remove oil, damage is assessed, and the wheels proceed to the wheel re-profiling area.

There are three common issues observed. If tires on the wheels are worn out, it is sent to the wheel re-profiling machine. If the tyre has to be replaced, the wheel goes through a series of processes, as the new tyre is cut, heated and placed on the wheel. The shaft of the wheel can be bent. In this case, the wheel is sent to the shaft straightener and the bent part of the shaft is



profiled. When the repairs are complete, the wheels are attached to traction motors, then placed on bogies and the top part of the locomotive is placed back.

There are three main sections in the wheel re-profiling area to complete these various repairs. There is the re-profiling section (W2), with a tyre-profiling machine, tyres are re-profiled often as a single tyre can be re-profiled up to four times before needed to be replaced. There is tyre preparation and replacement section (W3) which has various machines, cranes and an oven to correctly shape and attach the wheel to the tire. Tyres are brought in as a large circle of metal and are bored out. They are then heated and pressed onto the wheels so that they may be returned to the locomotive or wagon. At the back end of the re-profiling area, there is a bearing section (W4), where bearing work is completed to keep the wheels attached to their axle. This area contains all the tools and components necessary for repairs on bearings.

Commonly, a damaged tire would be removed from the wheel using a press to allow for quick reuse of the wheel. Yet the tyre press is inoperative in Windhoek, forcing the tyres to be cut to be removed which is a time consuming and unnecessary process. This leads to major time delays and waste of resources.

Locomotive brakes are under constant wear and tear and therefore must be maintained regularly. A contained brake room (W5) exists for this purpose and can be found alongside the small electrical room in the maintenance shop. Here brakes are taken and cleaned and repaired when necessary. No large machines are required for this maintenance process, a cleaning area and workbenches are necessary for the room.

### 3.2.2 Locomotive Cleaning (C)

When a locomotive is brought to the shop it must be cleaned to make sure it can be properly analysed along with making sure any debris is removed to stop future problems. Cleaning occurs right outside the shop in a cleaning area on the track leading to the disassembly area (C1). Here a large cleaning tank also sits to allow for cleaning of individual parts and components from the locomotives.

### 3.2.3 Engine Repairs (D)

The diesel engine of the locomotive acts as the source of power for the locomotive. The engine is complex and requires significant maintenance on certain parts to run efficiently. The components that need heavy maintenance are the cylinders and pistons, turbochargers, compressors, fans and the fuel intake.

Each locomotive in use by TransNamib has diesel engines that require twelve cylinders to be changed every eight years. All cylinder work is completed in its own section (D3). Once a cylinder has been removed and gone through its repair, it must be reinserted into its casing. The process involves heating the metal casing so it expands and placing the casing into a press where the cylinder is inserted. Once reinsertion is done, tests are performed to see if any cracks or leaks

remain; if there are none, the cylinder can be returned to the locomotive. If any malfunctions occur before the eight-year mark, the breakdown is analysed. If the repair is small (such as a crack to a single cylinder), then it can be repaired quickly without being removed from the locomotive. There is a gap in maintenance when a casing is damaged and needs heavy repair since it currently must be sent to Transnet in South Africa.

Turbochargers are standard on TransNamib locomotives. Therefore, a designated turbocharger maintenance area (D2) exists in the shop. For maintenance, a turbocharger must be removed from the engine and split into two pieces for anything internal to be done. Commonly the fan on the turbochargers is replaced, although most repairs are small and can be performed fairly easily. These repairs are hindered by the lack of spare parts for turbochargers and spare full turbochargers to be put into the locomotives. In the shop four locomotives were seen that could be put back into service if they had turbochargers.

The fan is used to assist in cooling the engine of the locomotive and by cooling down the water that is put through the radiator. TransNamib can currently do only a small amount of fan repairs in shop. Instead they must opt to send the fan to Transnet to be overhauled. Compressors must be removed from the locomotive for repair work. The common repair for the compressors involves fixing the valves since any leaks can cause problems and lead to more damage. The repairs are done by deconstructing compressors using hand tools and performing work on the internal valves. The compressor is then reconstructed and realigned by eye. Although a test stand would be ideal, compressors are only tested once they are returned to the locomotive. All fan and compressor work is completed in its own area of the repair shop (D4).

#### 3.2.4 Electrical Repairs (E)

Electrical work plays an important role in modern diesel locomotives. Multiple generators and motors have to work correctly for the locomotive to move. Therefore, electrical maintenance is an important section of the repair shop. This maintenance is divided between four main areas, the generator repair area (E4), the battery room (E1), the small electrical parts room (E3), and the traction motor area (E2). Both regular maintenance and heavy repair of a locomotive's electrical components occur in these areas.

The open generator maintenance area (E4) is where all main and auxiliary generators are repaired. It is located next to the wheel re-profiling area in the back side of the heavy repair building. Each are evaluated on separate metal stands, where TransNamib employees can access the wiring inside. Any wiring problems can be addressed by artisans in the shop, but any problems with the large metal external casing is handled by an outside company. This is due to the fact that the acid and steam bath usually used for casing cleaning is inoperative. Generators are only repaired and maintained in this area of the shop.



Batteries (E1) play an important role in allowing the locomotive to start moving. Yet, there is very little that can be done to repair a faulty battery. A locked room exists to store and test any batteries, and is located in the near end of the maintenance shop adjacent to the cleaning area. Upon noticing a problem with the batteries, they are removed from the locomotive and taken to the battery room. Here they are charged and tested for their ability to hold a charge. If the battery proves to hold a charge, it is returned to the locomotive, otherwise it is scrapped for a new battery. This room also provides storage for functional batteries that may be required for future locomotives.

In order to run effectively, a locomotive needs sufficiently organized and functioning wiring. All of this wiring work is done in the small contained electrical parts shop (E3) located in the maintenance shop. Here the entire locomotive wiring board can be maintained. In this shop there is a power source for testing and work areas for the small wiring work. The size of this shop in Windhoek is too small to allow for efficient work.

Traction motors (E2) are an essential part of a functioning locomotive, yet TransNamib has a limited ability to repair traction motors in-house. This shop does not have the ability to balance the poles of the motors and therefore has to outsource the majority of these repairs. An area does exist in the shop for traction motor repairs with includes inoperative acid steam bath also used for generators, yet this machinery is currently inoperative. A special lathe for undercutting of the traction motor armature also sits in the shop, yet is inoperative since blades for the machine can no longer be purchased. This small area exists next to the battery shop near the entrance to the maintenance shop.

### 3.2.5 Locomotive Running Maintenance and Inspections (R & I)

Running maintenance and inspection is done while locomotive remains intact with only small parts being removed. These checks are essential to the locomotives as they find small problems before they evolve into a larger issue. Included in the running maintenance and inspection section are a platform area, an inspection area, a painting area and a steam cleaning area. The platform (R1) is used by TransNamib workers for the damage assessment and allows for easy access to the underside and top of the locomotive, making checks easier. There is additionally an outside inspection area (I1) where the daily checks on a locomotive are performed before they are sent into service. The areas for cleaning and painting go together and are located on the track just past the platforms, allowing locomotives to be painted just before leaving the shop. Yet, locomotives are not regularly painted at the shop, and it commonly only happens when a locomotive is stabled for a period of time.

## 3.3 Rolling Stock Repairs and Maintenance

For rolling stock the repair processes are simpler and can be broken up into heavy repairs, and running repairs and maintenance. Heavy repairs require the disassembly of a wagon and the

processes completed revolve around wheels, welding and using a press to straighten out bent container walls. Running repairs for wagons involve painting and cleaning of the wagons to prepare them for new shipments.

### 3.3.1 Rolling Stock Heavy Repair

When an open top wagon arrives in the shed it is cleaned before the doors are removed from the main body to be straightened. A pneumatic press is used to flatten out the doors and remove any dents on the metal. Meanwhile, the floor of the body is cut away and refitted through welding on new metal plating. Improvements to the floor are sometimes added to help prevent rain damage and increase the durability of the wagon. Then the doors are reattached and the wagon is moved on to wheel repair. The wagon body is separated from the bogie using individual mechanical lifts or a forklift. The wheels are taken to the locomotive shop for re-profiling. This separation should happen with a crane to allow for a safe and quick process. Yet the carriage and wagon shop has limited capabilities to lift the wagons due to a lack of a crane in the area and is forced to use manual jacks or forklifts, which slows the wheel replacement process and overall wagon repair. After being fitted with new wheels, the wagons are sent to be sanded and painted.

Closed-top wagons commonly require less significant repairs when at the shop. When they arrive the insides are deep cleaned with steam in order to create a clean and safe working environment for any further repairs. Damages to the body can then be fixed through welding. These wagons will then also have their wheels replaced before being sent to sanding and painting.

### 3.3.2 Rolling Stock Maintenance

Before being sent off to be tested all wagons will be sandblasted and painted. The sandblasting booth sits outside near the wagon shed, and allows for removal of all rust from the wagons before painting. Sandblasting should happen inside a closed area to maximize efficiency and minimize the spread of sand, yet the carriage and wagon shop is not equipped with such a building. Therefore, this process occurs on the tracks outside. The wagons then continue down the line to the painting area where they will be spray painted. The wagons are then ready to be tested and returned to service.

### 3.3.3 Other Areas

There are several areas and rooms throughout the workshop used for non-repair purposes. There is an office area for administrators and top-level staff of the locomotive repair workshop. This area also provides space to store documents and provide a meeting place for staff to hold daily meetings. There is a clinic for the staff, a kitchen and ablution area. Inside of the workshop, there is an area for procurement, managed by operations and used by employees. There are various areas and rooms outside of the shop, such as the power station room, air compression room, fuel tank area, sand drying area, labs and washout building.

### 3.4 Staffing of the Windhoek Repair Workshop

We pinpointed gaps in the staffing ranks, by methodically identifying the current and desired staffing levels at the Windhoek repair which lead us to creating the following organogram seen in Figure 3.5 of all work ranks, whether they are filled or not at this time. The locomotive workshop has a head engineer and cascades down all the way to general workers. Below the senior engineer there are chiefs that each handle technical supervisors. Each technical supervisor has a staff of six to ten people that they have control over. The worker’s skills and level of importance are ranked using a letter system and number system with the head engineer being level “D” and the general workers level “A”.

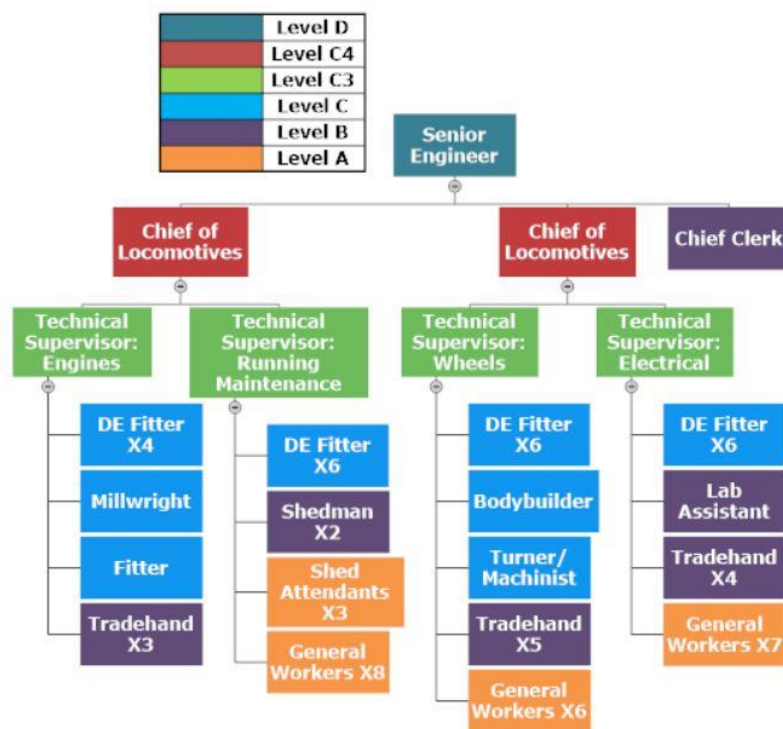


Figure 3.5 - Windhoek Locomotive Organogram

Each shop contains large groups of artisans that have different specialties including plumbing, bodybuilding, welding, and milling. These people are essential to any repair shop as they represent the people below the management that have the ability to perform complex repair tasks. There are also trade hands who are considered semi-skilled labour and work under the artisans. Finally, there are unskilled general workers who carry out basic work around the workshop.

Staffing for the Rolling stock has several similarities to the locomotive shop, as shown in Figure 3.6 below.

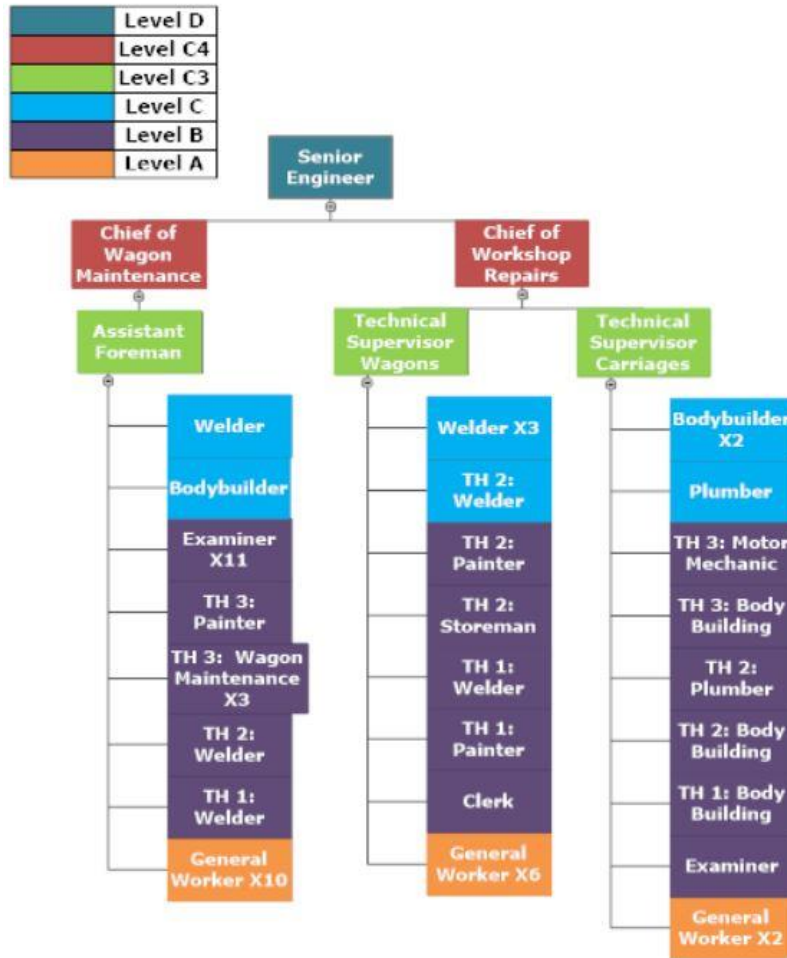


Figure 3.6 - Windhoek Rolling Stock Organogram

There remains an engineer and two chiefs, one for maintenance and one for repairs, both under control of the senior engineer. There is an assistant foreman who is in charge of the maintenance for the wagons or carriages that enter the shop. Underneath the chief of repairs are two technical supervisors, with one in charge of wagon and one in charge of carriages. Below the supervisors and foreman are once again a collection of semi-skilled labour with the addition of there being examiners to do the maintenance inspections on wagons. General workers again sit at the bottom of the organogram.

### 3.5 Improvements to the Windhoek Repair Shops

When we began work at the Windhoek diesel depot we were introduced to the managers and the technical supervisors that work with them. These technical supervisors have been working in the repair workshop for close to 30 years each and are masters of their craft. We proceeded to conduct formal interviews with the managers and asked for them to give us tours of their sections of the shop. Through our conversations with the supervisors we were able to identify three overarching limitations with the Windhoek repair workshop.

1. A lack of updated machinery and technology
2. A lack of semi-skilled manpower
3. Insufficient parts to complete repairs

The supervisors repeatedly informed us of these limitations in each interview. They spoke of how the repairs of locomotives were either significantly lengthened or stopped due to these issues. In our interviews with each supervisor, they pointed out machines they use that were either too old to function correctly or were long since broken. One of the largest offenders is the current wheel profiling machine; it used to be able to perform on two wheels at a time making so each axle only needed to be put into the machine once. Now, though, only one side can be worked on at a time. This inefficiency means that re-profiling wheels takes more than twice as long as before: the process of flipping the large wheel and re-profiling the other side is not easily done. Another example is the Tyre separator, a machine used to remove metal tyres from the wheel axles for reshaping.

The Windhoek shop is in possession of a refurbished separator from South Africa, but it has never functioned in this shop and it is unknown what is actually wrong with it. Instead of using this machine, the workers are forced to cut through the tyres to remove them. Updated versions of these two machines could significantly expedite the wheel repair process. There also some practices that still have to be done by hand due to the age of the shop. Compressors must be carefully aligned when being placed into the engine, and the process is currently measured by hand in the Windhoek shop. This process could be expedited by laser measurement. These interviews allowed us to see examples of places in the shop where machines were no longer able to function well, where machines didn't work at all, and where machines could be used.

The supervisor also had problems with the manpower of the repair workshop. We were shown entire labs which sat empty due to the fact there weren't enough employees to fill the lab. We were able to acquire the staffing information for the repair workshop. The staffing information shows vacancies in both the locomotive and rolling stock shops. The totals for the rolling stock show that 27 of the 86 total positions are vacant and 30 of the 75 positions in locomotives as well. The engine department has suffered from this as work they used to perform with cylinder refurbishment is no longer done because only one man has the training to do it and is already overworked.

The limited availability of parts also slows down the entire locomotive repair process. Through our time in the shop we found four locomotives nearly ready to be returned to service but lacked a turbocharger to be placed inside their engines. There is a definite lack of spare parts that occurs throughout the repair workshop. The cylinders could be overhauled in shop but the lack of simple kits with O rings means the cylinder casings must be shipped to South Africa. These both represent simple fixes that would allow more locomotives to be in service.

These problems culminate in the necessity to outsource repairs of multiple locomotive components to Transnet. Fans, Cylinder Casings, Traction Motors and Generator Casings are the four main parts that must be sent away. The fans must be sent away due to the lack of skilled manpower to properly overhaul these parts. The cylinder section currently sits full of cylinders waiting to be repaired, yet the lack of skilled artisans to complete the repairs leads to the parts being sent away so that engines can be quickly fixed and updated with fresh cylinders. Very little can be done to Traction Motors inside the shop due to the lack of proper machinery. The armatures of the traction motors must be undercut to allow for proper function of the motor using a lathe, yet this lathe sits inoperative inside the shop. The metal casings of the traction motors must also be cleaned before the motors can be returned to service. Previously an acid bath was used to clean these casings, yet this bath has fallen into disrepair due to the health concerns connected with the acids used, and the bath actually leaking acid. Therefore, these essential motors must be sent away for repairs. The generator casings also require a similar cleaning process before being reconnected with the internal generator parts. These casings are therefore also sent away for repair. The outsourcing of these repairs highlights the gaps in the workshop's capabilities and shows areas that can be improved in a new design.

Overall, the processes and workflow that exist in the shop were praised by the supervisors. Since the supervisors have spent an extensive amount of time working through these repairs, they have developed the most efficient and commonly cost effective methods of completing the repairs. The majority of improvements for the new shop then will stem from the implementation of modern machinery and the improvement of overall workflow.

### 3.6 Windhoek Machine Inventory

In an effort to fully understand the repair process that existed inside the Windhoek repair workshop, a complete inventory was made of the machines inside the shop. This information was collected through manual inspection of the machines and discussion with the technical supervisors of the shop. This inventory can be found below. A full list with quantity and manufacturers can be found in Appendix B.

List of **Wheel Repair Machines:**

- Wheel Re-profiler (Partially Operational)
- Shaft Straightener
- Wheel Cutter
- Wheel Heater
- Wheel Presser
- Tyre Press (Inoperative)
- Bearing Remover
- 500 Kg Crane

**Engine Machines:**

- Heating Oven
- Valve Grinder
- Disassembly Press
- Water Bath
- Crack Tester(Inoperative)
- 450 Kg Crane

**Machine Shop Components:**

- Plate Bender
- Plate Folder
- Plate Cutter
- Centre Lathe
- Shaper
- Thread Cutter
- Drill Press

**Other Machines:**

- Battery Charger
- Electric Drive Test Stand
- TM/MG Cleaning Bath
- Door Press
- 30 Ton Crane
- 7.5 Ton Crane
- 5 Ton Crane

**Exterior Components:**

- Boiler
- Air Compressor
- Sanding Station
- Sand Dryer

Running repairs do not require heavy machinery in the Windhoek repair workshop. Components are removed by hand or crane and most of the work is done by hand or with tools.

## 4 Design of the New Usakos Workshop

During colonial times, a steam locomotive repair shop was created in Usakos, about 166 Km north west of Windhoek (highlighted by the red dot on the map in Figure 4.1), where locomotives and rolling stock were serviced until the 1960's (Dierks, 2004).



Figure 4.1 - Rail map including Usakos

TransNamib trains still pass Usakos frequently, but the station building and repair workshop are abandoned and in serious disrepair. The town of Usakos was created due to its geographic importance as a strategic junction in the rail system, since it is located along the main corridor of rail travel in Namibia, from the Port of Walvis Bay north to Tsumeb and the Angolan border, as well as to the eastbound line to Windhoek. This central location makes it accessible to the majority of rail traffic in the country.

TransNamib still owns the station and the remnants of the adjoining repair shop. This existing infrastructure and key location make it an optimal choice for the possible location for a new repair workshop that would aid TransNamib in keeping repairs in house and efficient. In



order to address the problems of the current repair workshop in Windhoek, this new shop in Usakos will be able to efficiently maintain the rolling stock of TransNamib in close to proximity to the main areas of operation.

#### 4.1 Current Conditions at the Usakos Yard

On April 6, 2016, our team visited Usakos to evaluate the area for its viability as the location for a modern repair shop. While in Usakos, we met with the head of the Town Council and delved into our project with him. The town is supportive of the project and has tried to have the shop revived before.

The group was then able to inspect the land owned by TransNamib to get a detailed understanding of what is left of the original steam train repair shop (Figure 4.2). We recorded which structures could be adapted to our new design along with what would need to be demolished. Additionally, we acquired engineering drawings of the area with details about the former shop. Based on these documents we were able to identify changes to the current structures and other design constraints.

The remnants of a metal shed and the empty walls of the larger repair workshop can be seen in Figure 4.3, along with a large empty space where tracks used to run. The site contains a large flat portion of land overgrown with vegetation and trees. Standing beside this area are two large water towers, which when inspected, appeared reusable for the new workshop. Sitting opposite the surviving workshop building across the empty land sits a long thin building, which appears too small for any repairs but could be reused as office or living space. As a result of our visit, we concluded that the land is well suited for the placement of a new shop and that almost all the infrastructure will need to be rebuilt.



*Figure 4.2 - Usakos Buildings*

Although there is one large building that was formerly used for the heavy repair of locomotives that remains structurally intact, it is too small to be used for today's diesel electric locomotives, which are larger and heavier than their steam powered ancestors. Nevertheless, given the size of the structure, we concluded that the extant building would be a reasonable location to stage wagon repairs for the new repair shop.



*Figure 4.3 - Former Repair Shop Building in Usakos*

Within the overall design boundaries, we wanted to create an efficient layout with a location for each sub shop. This technique was chosen to create a detailed design, which allows for the estimation of the costs to be performed. Our preliminary site and construction designs will form the basis for subsequent engineering drawings by TransNamib professionals.

## 4.2 Design Criteria and Constraints

As any engineering project requires, our design process began with understanding the constraints. Spatial boundaries were the first and most important constraint to understand. The restrictions for the placement of new roads and rail had to be understood through analysis of the existing infrastructure. Then the criteria for the new workshop design given by TransNamib was implemented. Then to work to save building costs by analysing what structures could be reused.

To determine the **spatial extent** of the overall rail yard we consulted with TransNamib's Real Estate Department on what parcels were still owned by TransNamib. This information showed us how far east the shop could extend and provided a boundary for our possible area. The main rail line that forms a large "S" shape running through the city provided a boundary to both the North and West side. The sharp drop in elevation towards the river on the South side provided a southern boundary for our designs. This left the area shown in figure XX as the possible location of our new workshop. Then in order to accommodate the existing rail structure and the surviving workshop building, the southern side of the land was chosen as the main design area.

Since new **roads** would have to be laid for the workshop, the road infrastructure of Usakos was analysed to understand how best to connect this area to the existing road network. Usakos is already an established town with roads surrounding the yard, so a road map was used throughout the design process. Multiple options were considered for where to place the main road entrance to the workshop. It was important to make sure the road connected to both the workshop and the office area while crossing the least amount of rail possible. The road placement also had to allow for easy entrance for any trucks and vehicles coming to the workshop. All of these constraints were taken into account when deciding the placement of the road.

As with any rail yard, **rail lines** would have to be laid throughout the area in order to properly allow for movement of locomotives and wagons. The rail had to have an entrance off of the main line to give access to the workshop area. This entrance had to come from the second or third line so that a runaway train is unable to enter the workshop area. The entrance also must allow for a **clear division** between area controlled by the Operations and Engineering departments of TransNamib. This space allows for locomotives and rolling stock to be dropped off and picked up for repair. Another important rail feature is an allotted area for a **large triangle of rail for turning around** of the locomotives. This allowed for reverse movement of the locomotives around the shop. In order to allow these locomotives and wagons to be moved around easily, extra rail has to be added to allow for proper shunting. The rail then had to provide access



to the locomotive heavy repair, maintenance and inspection areas along with the wagon shop. It was decided that all track would continue all the way through all the workshops besides the heavy repairs shop, to allow a continuous flow of locomotives and wagons in one direction. This would greatly increase efficiency since a locomotive or wagon would never be trapped on both sides and backed up. All of these restrictions had to be met so that the rail could properly service the entire workshop.

The location of new infrastructure in the Usakos yard depended heavily on the **remaining buildings**. In order to lessen costs and possibly preserve the aged buildings, it was decided that our designs would be built around the surviving buildings when feasible. Since the workshop building could be reused, this would require the main workshop to reside on the southern section of the land with this building.

One major criteria for the new design was to **locate the locomotive and wagon shops next to each other**, since they share several repair processes, especially with respect to the maintenance of wheels. This highly desirable change would mean that the whole workshop must now be organized together in one area as opposed to two self-sufficient separated sections as is the case in Windhoek. In addition to the repair buildings and shops, our designs had to allow for offices, ablutions, a canteen, a classroom, and meeting rooms for the personnel of the workshop. Workshop support buildings such as an **effluent plant, water tanks, oil tanks, sand storage**, an **air compressor** building and a **power substation** are all necessary for proper function of the workshop and therefore need to be situated correctly.

The final constraint map is shown in Figure 4.4 below.



Figure 4.4 - Area with Design Constraints

### 4.3 Overall Site Design

For our design we wanted to reuse the remaining structures as much as possible. After reusing the remaining structures, the additional buildings were established around these structures. We started with the essential workshop and worked outward with the accessory buildings and then roads and rails. The essential workshop can be seen below in Figure 4.5

The existing large building in the south was allocated to the **wagon area**. We were not able to analyse the structural condition of the building and leave the decision to TransNamib civil engineers on whether or not it will be used. To connect the repair workshops, the locomotive **maintenance** and **inspection** areas were placed in parallel with the wagon shop. In between these two main buildings, we placed the **repair shops** so that they could service both wagons and locomotives with minimal wasted movement of people and parts. The wagon and locomotive halls would have a total of ten tracks that would run through the entire building, entering at one end and exiting at the other end to allow first-in-first-out processing of repairs with no backups.



Figure 4.5 - Essential Workshop

Adjoining the main workshops, we arranged different buildings for **heavy repairs, light repairs, cleaning** and **painting** bays. The heavy repairs section deals with wheels both from wagons and locomotives, hence it is placed directly in-between the corresponding tracks. The cleaning and painting areas are also shared between locomotives and wagons, so we designed the access accordingly.

The next step was to come up with designs for the secondary buildings, which are shown in Figure 4.6 and include:

- a 720 sq. m Dining hall with kitchens,
- 2,158 sq. m of Offices for supervisors,
- 3,100 sq. m for locker rooms and showers
- 675 sq. m of Training Centre
- 52 sq. m of Clinic

We included one of the present buildings, highlighted as light grey, to our layout. The areas in between the ablutions were assigned as parking spaces. We also made provisions for a scrap yard in the northernmost side of our layout as seen below. This area will serve as a disassembly point for locomotives and wagons to get scrapped and shipped out. We also drew buildings, which will serve as classrooms for apprentices (labelled as “school” in Figure 4.6), a clinic and a security office.

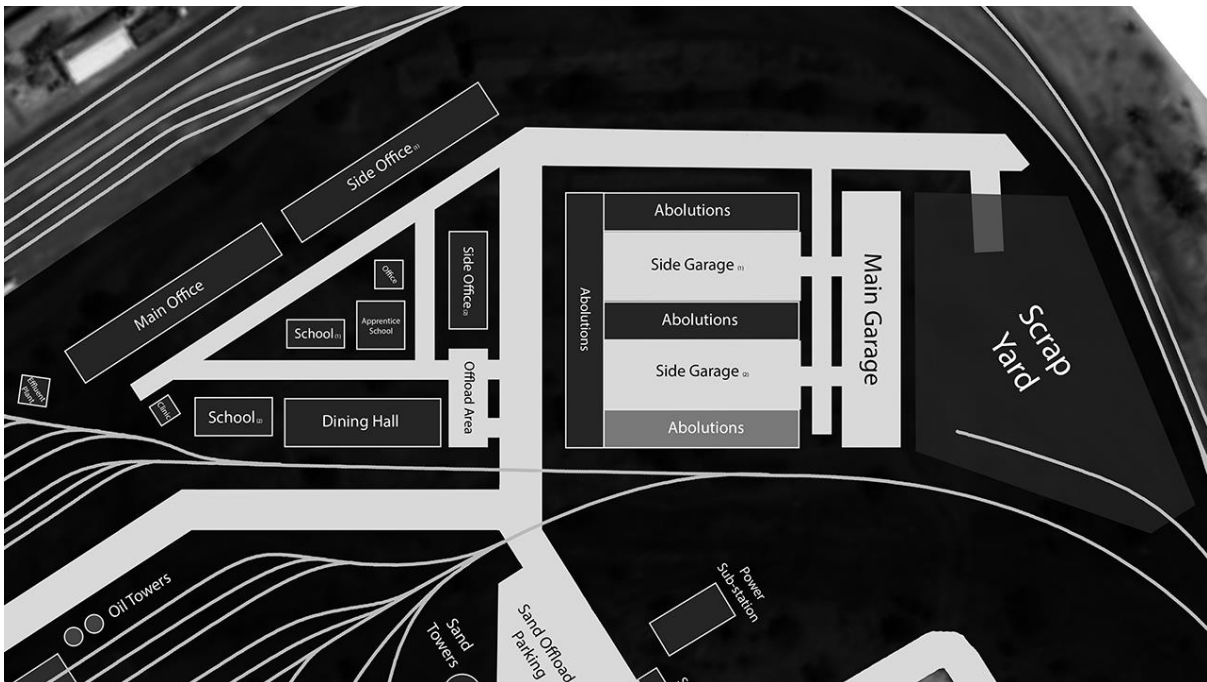


Figure 4.6 - Secondary Buildings

Once we were done with the main buildings, **roads** were laid out to serve as efficient means of transportation for employees and for the delivery of goods. There are two 6m-wide main roads in our layout totalling 500 meters in length, one that goes to the workshop and the other to the secondary area. The main purpose of our workshop road is to provide a convenient path for incoming trucks to deliver parts to the procurement division. We created a 280 sq. m offloading area attached to the procurement area, which could provide enough space for trucks to offload the goods and turn around by making a three way turn. The northern segment of road reaches up to the scrap yard, giving TransNamib the ability to bring in trucks to pick up the scrapped



locomotive and wagon parts for removal off the premises. This branch also serves as the main artery that serves the parking garage, offices and auxiliary personnel buildings.

The **rail tracks** were laid out to allow the efficient shunting and repair of locomotives and wagons. The workshop has two entrances, one from the West and one from North, for trains approaching from the eastern side. There are secondary rails to safely take trains from these connections to each of the individual workshop areas. The large triangle on the east of our workshop serves as a convenient three-way turn for trains. In all, we calculate that 6.7 Km of new rails will have to be installed in the new workshop. The general layout design with main rail and road lines can be seen in Figure 4.7.



Figure 4.7 - The General Design with Rails and Roads

The final step in our designs was to add the **minor buildings**. First we added structures to handle water. Two large **water tanks** and a **water tower** are still in operational today and were integrated into our designs. It is necessary to pipe clean water from these structures to supply offices that are both in the main workshop and also the secondary areas. There must also be an **effluent plant** to deal with unclean water contaminated by various processes in the shop. Since laying out pipes is a simple process, we suggest straight lines, with minimal branching, from water tanks and the effluent to the supply and remove water from the structures.

To handle electricity, we planned a 250 sq. m. **power substation** to supply electricity to the workshop and surrounding infrastructure. We suggest to follow the main roads for electrical line leading into the repair shop.

**Compressed air** is another essential system for a repair workshop. Therefore, a building was created to hold two air compressors, allowing for the shop to still run if one of the compressors became inoperative.

Another important area for our design was sanding. We created a sand offload parking lot and rail for sand arriving by truck or train, two **sand storage** towers, a **sand purification** building and a **sandblasting building** for wagons. Since sand is loaded onto locomotives in the inspection area, installing underground pipes that go from sand towers to the inspection area for sanding will be necessary.

Other necessary supplies include **oil** for locomotives and **fuel** for engine operation. We have dedicated tanks for both, which are neighbouring the inspection area, giving easy access to these structures. Our final exterior design including all Workshop support structures can be seen in Figure 4.8.





Figure 4.8 - Final Exterior Design

#### 4.4 Internal Workshop Layouts

Once the exterior design was finished, we proceeded with the design of the interior of the heavy and light repair areas. This interior design of the new workshop focused on maximizing the efficiency and workflow of the processes inside the shop through careful placement of each sub-shop. The completed interior design can be seen in Figure 4.9.

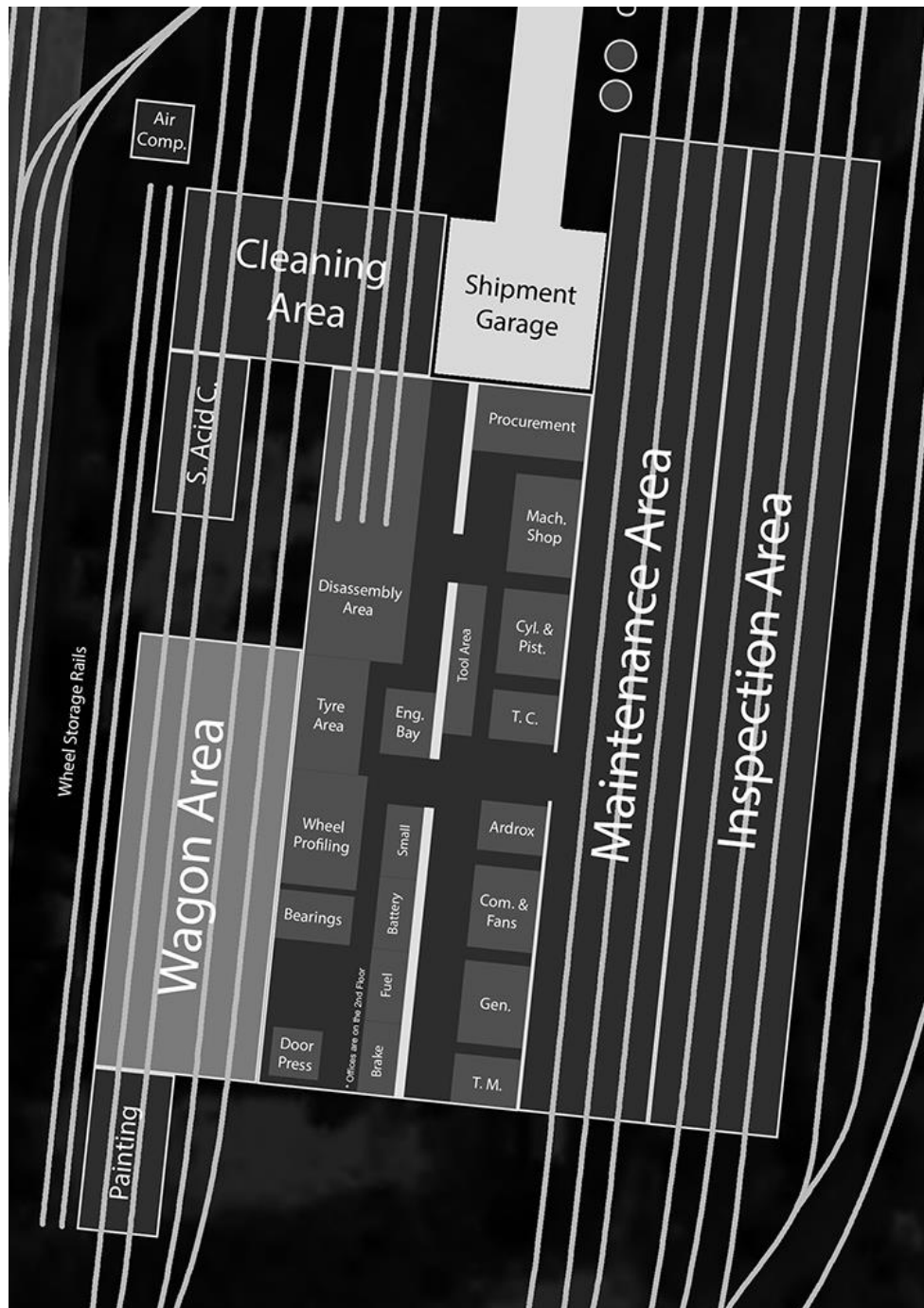


Figure 4.9 -Final Interior Design

The main focus was to divide the shops based on the need for **cranes**. The heavy repair shop located on the left side will hold two large 45 ton cranes. These cranes are used to lift full locomotives in order to access the bogies and to move the 16 ton engines. The locomotives are

separated from the bogies in the disassembly area which is equipped with pits and rail tracks for the locomotives. Therefore, the **engine bay**, where full engine blocks are assembled is located adjacent to the **disassembly area**. Besides separating the locomotives from the bogies, the disassembly area is also used for removing the wheels from the bogie. From there, wheels must be moved to the **wheel, tyre and bearing** maintenance areas. Therefore, these areas were placed alongside the disassembly area to allow for easy movement of wheels in and out.

The three sub-shops responsible for wheel maintenance also serve both the locomotive and wagon workshops. Therefore, the line of wheel sub-shops is also accessible to the wagon sheds. The **door press** and other fixed wagon machinery will therefore also be located adjacent to wagon sheds.

The four enclosed shops responsible for **brakes work, fuel management, battery testing** and small **electrical** work were then placed along the wall to best utilize the remaining space. The size of these shops was increased from their counterparts in Windhoek to allow for them to be properly utilized. The **supervisor's offices** were then placed on top of the enclosed shops to allow the supervisors to oversee more of the workshop from their office. This move also opened up more space for **component repair** in the heavy repair hall.

The two easternmost sections of the shop -- the **part repair** shop and **running repair** platforms -- depend on 3 much **smaller cranes** of 7.5 tons and were therefore sectioned together. The **part shop** contains **5 different mechanical repair areas** (cylinders and pistons, turbochargers, compressors and fans, generators and traction motors) along with the **machine shop, tool shop, ardrex tank, and procurement shop**. These shops are located to allow for parts to be moved directly in and out of the locomotives from their respective shops.

The **machine shop** is located on the north side close to the wheel section to allow one supervisor to oversee both sections. Cylinders and pistons, turbochargers and compressors and fans all require cleaning in the ardrex tank and are therefore located around the tank. Traction motors and generator casings both require steam cleaning and heating so they are located next to each other to allow for shared use of that equipment. Cylinders and pistons must be removed directly from the engine block, so that section is located close the engine bay.

Next to the **part repair shop** is the **running maintenance** section which holds 3 tracks with platforms for full inspection and locomotive access. The 7.5 ton cranes will span across the running maintenance and middle shop. The **inspection** area consists of 5 rails running adjacent to the platform building. Two of these tracks run under sheds to allow for inspections on locomotives. Pits will also be built underneath the sheds to give access to the bogies. Two 45 m pits will be constructed with room for two locomotives each. The other three rails that make up this section will be used for moving and shunting of locomotives. On the North side of the inspection area sit two **sanding towers** and two **fuelling stations**.

The **wagon repair shop** will be built next to the locomotive heavy shop, inside the existing buildings of the old steam train workshop. Wagon maintenance requires an open area with tracks for wagon movement. A **twenty-ton crane** will be installed to allow for wagons to be lifted off the bogies for wheel repairs. The adjacent wheel repair equipment will be used to re-profile the wagon wheels.

#### 4.5 Workshop Equipment & Costs

An inventory of modern machinery is essential to the creation of a modern repair workshop. An overview of the requested equipment supplied by TransNamib can be found in Appendix A (K. Kufawada, personal communication, February, 9, 2016). This list was then expanded based on our interviews with workshop managers. Current models of the required machines were identified and evaluated for use in Usakos. Approximate costs in Namibian Dollars were then obtained from TransNamib employees for each machine. The costs were added together to give a **total equipment cost of N\$104,530,000**.

The tables that follow list all of the equipment needed for full operation at the new Usakos Repair Shop. The bolded machines shown below highlight significantly updated versions of aged machines found in the Windhoek shop, or entirely new systems added in an attempt to improve the repair efficiency and modernize the workshop.

##### Wheel Section:

Machine Name	#	Pricing	Manufacturer
Wheel Re-profiler	1	10 Million	Hegenscheidt
<b>Portable Wheel Lathe</b>	1	N/A	Delta Manufacturing
Wheel Cutter	1	400,000	Webster & Bennet
Wheel Heater	1	500,000	GH Induction
Wheel Fitter	1	500,000	Hegenscheidt
<b>Wheel Press and CNC Lathe</b>	1	5 Million	Hegenscheidt
Bearing Cleaner	1	150,000	Stingray Parts
Full Bearing Bay	1	2 Million	N/A
450 KG Crane	1	300,000	Morris

**Machine Shop:**

Machine Name	#	Pricing	Manufacturer
Plate Bender	1	800,000	Morgan/Knuth
Large Drill Press	1	1.5 Million	Knuth
Small Drill Press	1	150,000	Knuth
Grinder	1	70,000	Knuth
Threading Machine	1	50,000	Rigid 535
Big Centre Lathe	1	2 Million	Haas
Small Centre Lathe	1	1 Million	Haas
Guillotine	1	1 Million	Baleigh Industrial

**Other Machines:**

Machine Name	#	Pricing	Manufacturer
Battery Charger	1	50,000	Staticon
Electric Drive Test Bay	1	1 Million	Woodward
Fuel Calibrator	1	1 Million	Woodward
Wagon Hydraulic Door Press + Base	1	200,000	IMCAR
45 T Cranes	3	30 Million	Morris Cranes
7.5 Ton Cranes	3	9 Million	Morris Cranes
20 Ton Crane	1	15 Million	Morris Cranes
<b>Steam Cleaner</b>	1	150,000	Goodway
<b>Large Industrial Oven for TM and MG</b>	1	300,000	N/A
<b>Armature Undercut Machine</b>	1	1 Million	CAM Innovation

<b>Laser Alignment Tool</b>	1	50,000	Acuity Laser
<b>Compressor Running Machine</b>	1	1 Million	Self-Build
<b>Locomotive Load Box</b>	1	2 Million	Cressall

#### **Engine Machines:**

Machine Name	#	Pricing	Manufacturer
Heating Oven	1	100,000	Talfurnco
Disassembly Press	1	100,000	Powerteam
Water Bath for Pressure Testing	1	10,000	Self Build
<b>Crack Tester</b>	1	250,000	Magnaflux
<b>Rotor Balancer</b>	1	1 Million	JP-Balancer
500 Kg Crane	1	250,000	Morris Cranes

#### **Exterior Components:**

Machine Name	#	Pricing	Manufacturer
Sand Blasting Room	1	2.5 Million	Progressive Surface
Sand Filling Station	2	100,000	Macton
<b>Painting Room</b>	1	2.5 Million	N/A
<b>Sulphuric Acid Cleaning Sump</b>	1	3.5 Million	N/A
Sand Dryer Building	1	50,000	Carrier
Air Compressor	2	2 Million	Ingersoll Rand
Boiler and Heated Cleaning Tank	1	4 Million	ZG Boiler and Vessel
3 Ton Forklift	1	500,000	Manitou

7 Ton Forklift	1	1 Million	Manitou
Lifting Equipment	1	7.5 Million	N/A
Welding Equipment	1	2.5 Million	N/A

New machines found for the wheel section include the **Portable Wheel Lathe** and Wheel Press and CNC lathe. At first, the idea of an underfloor wheel lathe was investigated in the hopes of eliminating the need to remove the wheels from the bogies. Yet the small size of the TransNamib fleet in comparison to the immense costs of such a machine made it an unnecessary investment. Therefore, a smaller portable wheel lathe has been suggested. This would allow for quick re-profiling of wheels on a locomotive or wagon that isn't in need of a full bogie disassembly. This machine can be easily attached directly to the wheels on the rail without any heavy lifting of the machinery. The **Wheel Press and Lathe** would replace the inoperative wheel press that currently exists in Windhoek. This would remove the traction tyres from the wheels using the press and then the CNC lathe would reshape the tyre so that it could be used again. The Wheel Press and Lathe, while increasing the life of the tyres, was deemed unnecessary by the two senior engineers questioned due to its significant price, and how rarely this process would be needed in a TransNamib shop.

It was found that the engine shop would greatly benefit from the addition of a new Crack Tester and Rotor Balancer. The **Crack Tester** is used to evaluate the strength of the cylinder casings before they are placed in an engine. The Windhoek tester hasn't worked in a significant period of time, yet a crack testing machine was strongly recommended in interviews with technical supervisors. The **Rotor Balancer** is a machine that allows for realignment of the turbochargers. This machine would allow for testing and repairs of turbochargers that can't currently be completed by TransNamib. These two machines would allow for quicker and more complete repairs in the engine shop.

The electrical shop is currently missing three machines that would greatly help the repair process. A **Steam Cleaner, Industrial Oven** and **Armature Lathe** will be included with the new design. As previously stated the traction motors need a lathe and cleaning system to be properly repaired. Therefore, a steam cleaning system and industrial oven were found to be the best options to replace the outdated acid cleaning system. This steam cleaner and oven could allow for both generator and traction motor casings to be easily and effectively cleaned, instead of having to be outsourced. A new CNC armature lathe would be included in the Usakos shop to allow for reshaping of the traction motor body as well. These three pieces of machinery would keep major electrical repairs in-house.



Extra testing equipment was also deemed as necessary for the new Usakos workshop. A Compressor test box, Locomotive load box, and Laser alignment equipment were found to be very helpful to the repair process. In the current repair process, compressors must be loaded into the locomotive to be tested. A **compressor test system** would allow for testing of the large components without the extensive process of placing them in the locomotive. A **locomotive load box** would serve a similar function, testing the internal components of the locomotive while it is on the platform. This will let problems be detected before the locomotive returns to active duty. **Laser alignment equipment** for compressors was a direct request from the technical supervisor in Windhoek responsible for compressor repairs. He explained that the current process of installing compressors is done by hand measurement, and can be time consuming and often incorrect. Using lasers would allow for quick and accurate placement of engine components into the locomotive.

Two large gaps were found in the outdoor machines and buildings of the Windhoek repair shop. Currently, there is limited infrastructure for painting and sandblasting of both wagons and locomotives in a TransNamib workshop. Both of these processes are completed outdoors on extra rail in an open air environment. Therefore, it is suggested that an **enclosed painting building** and **enclosed sandblasting building** be established in Usakos. The sandblasting building has the option of using both sand and metal grit for its cleaning process. Sand is the established medium for this method and is readily available in Namibia, even though metal grit is the new modern medium for this process. TransNamib will have to choose which option better suits the workshop when the final planning is undertaken.

These new and modernized machines will allow TransNamib to complete repairs more efficiently and to overhaul components that were previously sent away for repair.



## 4.6 Workshop Staffing and Costs

Using the ideal staffing for the Windhoek workshop as a basis, the Organogram in Figure 4.10 was developed for the new Usakos repair shop.

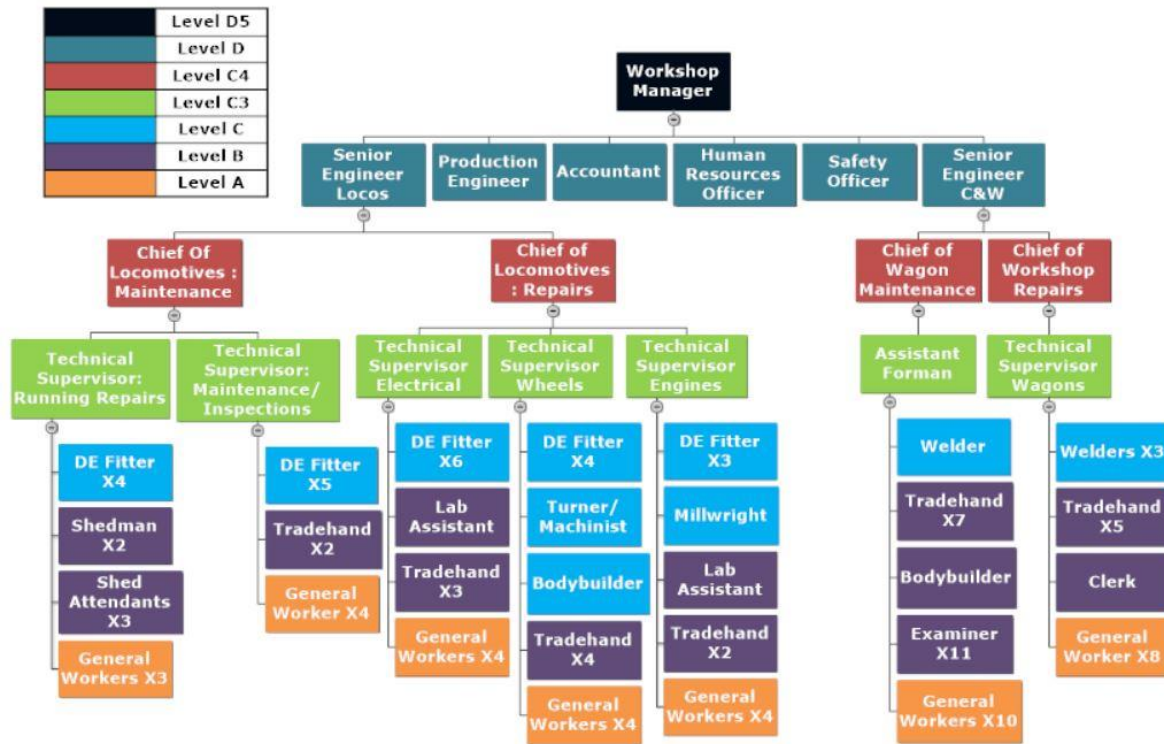


Figure 4.10 - Organogram of the new Usakos Repair Shop

Our goal was to merge the locomotive and rolling stock shops into one and remove unnecessary positions. This led to the creation of a new position above the senior engineers to make sure there is collaboration and communication between the two sections. The position is referred to as the **“Workshop Manager”** and has a level above the senior engineers. There are several other changes from the former staffing as well. This shop will not be made to handle carriages and as a result, their staffing has been eliminated. The change is because carriages represent a small portion of the TransNamib fleet and the ability to repair them in Windhoek is sufficient.

Even though the ideal staffing in Windhoek has room for three chiefs of locomotives two would work more efficiently as well as being what is requested by the senior engineer in the Windhoek repair hall. This also allows locomotives to have a system similar to rolling stock where there is **one chief for repairs** and **one for maintenance**. We have also made the decision to promote the assistant from level B3 to C3 because as someone in charge of significant staff he should have higher qualifications than the people who work under him. There was also the addition of a **lab assistant** to the Fuel lab as we felt another staff member in charge of the Fuel lab was required.

Additionally, there are several new staff members on the managerial level; the **production engineer, accountant and safety officer**. Usakos does not have the proximity to the head office that the current repair hall in Windhoek so the additional managerial positions were essential. These positions will additionally take pressure off the senior engineers because as of now they are in charge of the responsibilities that these four positions entail.

To find the cost of the staffing we communicated with TransNamib’s Human Resources department to acquire the **average cost for each level of staffing**. With the Organogram already made the department was easily able to send us the information about out the payment for the different levels of staffing.

<b>GRADE</b>	<b>AVERAGE REMUNERATION IN N\$</b>
D5	550,000
D	350,000
C4	215,600
C3	185,500
C	160,000
B	87,800
A	48,200

Using the exact costs for the numbered levels shown on the Organogram in Figure XX and the medians for grades A, B and C, we estimate that the **annual staffing cost at the new Usakos shop will be N\$14,381,900**.

### 4.7 Overall Cost Analysis

Based on the estimates described in sections 4.5, 4.6 and 4.7 above, we have developed a projection of the total costs for the creation of the new Usakos Repair Shop. These costs are displayed in Figure 4.11 below. Building costs were calculated using average prices gained from TransNamib. For the buildings, we used a flat cost of N\$8,000 per meter squared and took the dimensions of all the buildings from our drawings to calculate the 18,000 meters squared of building. For the rail, the 6.7 kilometres of new track for the entire shop may be built at a cost of approximately N\$ 4,000,000 per kilometre.

Construction Cost:	N\$150,000,000
Rail Cost:	N\$27,000,000
Equipment Cost:	N\$104,530,000

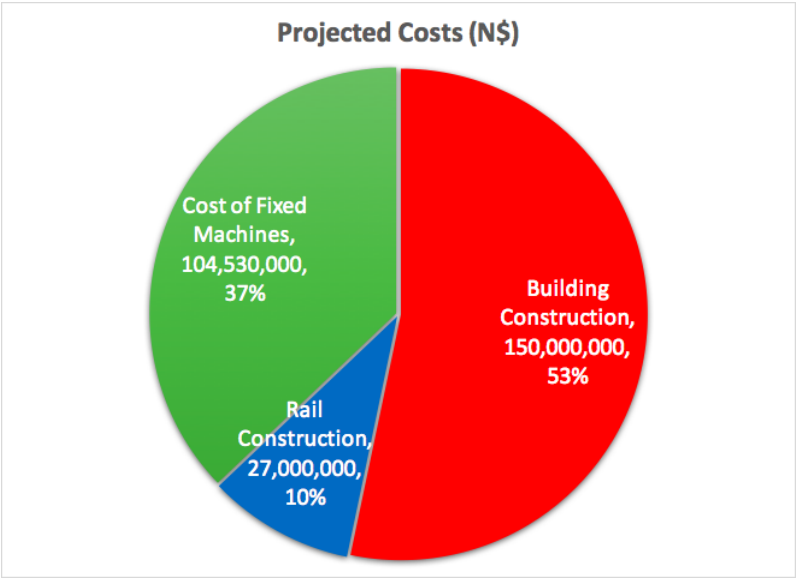


Figure 4.11 - Projected Costs

## 5 Benefits of the New Usakos Workshop

The benefits of a new repair shop are substantial, to TransNamib, to the community of Usakos, and to Namibia. These are not as easy to quantify as construction or operational costs. Nevertheless, a new repair shop in in Usakos will have the following benefits:

1. Creation of jobs for Usakos
2. Elimination of outsourcing costs
3. Increase in load carrying capacity
4. Efficiency gains throughout the repair system
5. Opportunity to improve the Windhoek Repair Workshop
6. Elimination of wasteful transfers to Windhoek for repairs

The new repair shop also represents a **benefit for the city of Usakos**. The city was built up around the rail yard and without the shop the population has slowly dwindled. In our talks with the town council, we learned that they have been attempting to get the shop re-established for the past 10 years. Their concern is justified as the unemployment in Usakos hovers around 40-60% for the city.

The new workshop, when fully staffed, would allow for the **creation of 133 permanent jobs** along with the opportunity for the city's people to assist in the construction of the shop. A training centre included in the workshop will allow the employees to gain new skills and knowledge improving their level of employment. A repair shop established Usakos will allow the city to be revitalized.

TransNamib currently outsources a significant number of repairs to Transnet. The most commonly outsourced parts are the cylinder casings, fans, generators and traction motors. The new and additional machines proposed in this report while representing a significant upfront cost, will allow TransNamib to achieve long term savings by **conducting all their repairs in-house**. Additionally, the new machines are the next step in TransNamib becoming self-sufficient and less reliant on the resources and infrastructures of South Africa.

Walvis Bay is an expanding port and rail is an important component of Namibia's logistics infrastructure for moving materials and products inland or for shipping Namibian products or raw materials to the rest of the world. Currently, TransNamib is not operating at its optimal capacity and its contributions to the Namibian economy will be enhanced with the creation of a new repair workshop. As we have mentioned before the CEO of TransNamib has stated that the

current need is 15 trains per day but they are currently running 15 trains a week. The new Usakos workshop will **greatly increase the daily carrying capacity** of the TransNamib fleet.

TransNamib's only active workshop in Windhoek opened in 1960 and the machines and practices there have become outdated. The updates to the repair system and the layout of the shop in Usakos will allow for **repair processes to be done much more efficiently**. The changes create an increase in value added time for the shop, meaning that time is not wasted with processes such as moving parts or even an entire locomotive when it is being repaired. Thus, TransNamib will benefit from the reduced time that locomotives spend in the repair shop, and increasing the number available in the active fleet. The new shop will also be made to service new locomotives, allowing TransNamib to continue buying new locomotives that will be more reliable and require less maintenance than the ones that currently make up the majority of their fleet.

A new repair shop in Usakos also creates the **opportunity to improve the Windhoek repair workshop**. Currently, the Windhoek shop cannot be closed even briefly for updates, as this would halt repair and maintenance for all of TransNamib's fleet. TransNamib also has plans to incorporate a new commuter rail into Windhoek which would be used to transport workers who live outside the city into Windhoek. The facility in Windhoek could be adapted to serve those plans.

With a new repair shop, Usakos can return to being the hub of rail repairs and the centre of the active rail network. If the shop is implemented the accidents that happen on the Walvis bay to Tsumeb line will no longer need to be transported the long distance back to Windhoek. This results in **savings on transportation costs** and allows for an accident to not hamper the rail lines.

The creation of this new rolling stock repair shop will allow for TransNamib and the Namibian economy to take immense strides. A modern repair shop allows for increased trade in all forms, an expedited repair process, and the ability for TransNamib to purchase newer rolling stock. This new repair shop will put more active locomotives on the mainlines, increasing the volume of cargo shipped by rail in and out of Walvis Bay. This will **increase profits for TransNamib** and reduced the subsidies required by the Namibian state. The repair shop in Usakos will require significant government funding to be established. In comparison to the substantial, long-term benefits of fuller employment and the economic development of Namibia as a whole, **a new repair shop in Usakos represents an investment in Namibia's future prosperity**.

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# Appendix A: List of Necessary Workshop Components

- General test, disassembly, and repair machinery
  - Load Box for Locomotive Testing
  - Repair Systems for:
    - Locomotive Wheels
    - Electrical Rotating Equipment
      - Traction Motors, Alternators, Aux. Generator, Blowers
    - Specific Engine Components
    - Auxiliary Machine Components
      - Compressors, Gearboxes
    - Welding Work
- Cleaning System
  - To clean sulphuric acid from rolling stock
  - Includes neutralizing bay to treat the tank
- Storage Rooms
  - To keep spare rolling stock and parts
  - Storage for minor repair equipment
- Sand blasting system
  - To clean manufactured parts
- Paint booth
  - To paint finished components
- Petrol tanks & Fuel Lines
  - To store and carry fuel
- Fuel fired boiler
  - To conduct steam cleaning
- Power supplies
  - To power the repair systems
- Water supply system
  - To supply water for machinery
  - To supply water for employees
- Lifting equipment (Crane)
  - To lift trains and parts for repairs
- Separate rail lines in the shop
  - To conduct simultaneous repairs
- Effluent Plant
- Administrative Offices
- Canteen and Ablutions



## Appendix B: Full Windhoek Machine Inventory

### List of Wheel Repair Machines:

Machine Name	#	Manufacturer
Wheel Re-profiler(Partially Operational)	1	Hegenscheidt
Shaft Straightener	1	Hegenscheidt
Wheel Cutter	2	Webster & Bennetl
Wheel Heater	1	Elin
Wheel Presser	1	B&S Massey
Tyre Press (Inoperative)	1	Bencor
Bearing Remover	1	Owatanna
500 Kg Crane	1	VNW

### Engine Machines:

Machine Name	#	Manufacturer
Heating Oven	1	Talfurnco
Valve Grinder	1	Siouxtools
Disassembly Press	1	Powerteam
Water Bath	1	Gewis
Crack Tester(Inoperative)	1	Magnaflux
450 Kg Crane	1	VNW

### Machine Shop Components:

Machine Name	#	Manufacturer
Plate Bender	1	Morgan
Plate Folder	1	Roma
Plate Cutter	1	Morgan
Centre Lathe	1	TOS

Centre Lathe	1	VDF
Centre Lathe	1	Ward
Centre Lathe	1	ZPB
Shaper	1	Ormerod
Thread Cutter	1	Rigid 535
Drill Press	2	Corona
Large Drill Press	1	Asquith

**Other Machines:**

Machine Name	#	Manufacturer
Battery Charger	1	B&H Electric
Electric Drive Test Stand	1	Woodward
TM/ MG Degreasing Bath (Inoperative)	1	African Explosive and Chemical
Door Press	1	Century Engineering
100 Ton Cranes	3	Morris Cranes
7.5 Ton Crane	1	H.R. Lasch
5 Ton Crane	3	Morris Cranes
5 Ton Crane	1	H.R. Lasch

**Exterior Components:**

Machine Name	#	Manufacturer
Boiler	1	
Air Compressor	1	
Sand Filling Station	1	
Sand Dryer	1	Custom Build

## Appendix C: Shop Observation Protocols

What machines are present in the shop?

Where in the shop are the machines present (layout)?

What is the order of operations for a piece of rolling stock?

Any blatant areas of improvement you can see currently?

## Appendix D: Interview Questions

Hi, we are a group of students from Worcester Polytechnic University in the US, and we are currently working with TransNamib to help design a new repair shop in the city of Usakos. In order to complete this task, we are interviewing managers like yourself in order to gain a better understanding about the successes of the current repair process and what can be improved in the Windhoek repair hall. The final results of our project will be published and used by TransNamib in future work. Yet, we are focused solely on the machines and repair technologies involved with your work and the repair process as a whole, therefore names and any other identifiable information will not be included in the report and individual responses may not even be published. This process will take about 10-15 minutes. This survey is completely voluntary, and you are free to not answer any question you do not feel comfortable with. Are there any questions that you have about this interview or our project and would you like to take the survey?

WPI IQP 2016

TransNamib Rolling Stock Revival

Windhoek Repair Workshop Employee Survey

1. What is your position?
2. What processes in the shop do you manage?
3. What is the most common repair or job you carry out?
4. What is the biggest problem that you see with the current process?
5. What is the biggest success that you see with the current process?
6. What is the best method in your view to solve this problem?
7. What would be the best possible addition to this shop?

## Appendix E: Interview #1

WPI IQP 2016

TransNamib Rolling Stock Revival

Windhoek Repair Workshop Employee Survey

Interview #1

1. What is your position?

Locomotive Technical Supervisor

2. What processes in the shop do you manage?

Daily Locomotive Maintenance, Major Repairs, the Machine Shop, Welding Shop, Paint Shop, Collision Repairs

3. What is the most common repair or job you carry out?

Collision Repairs, Assembling and Repairing Traction Motors, Wheel Profiling

4. What is the biggest problem that you see with the current process?

Old Tools, Outdated or Missing Machines

5. What is the biggest success that you see with the current process?

Knowledgeable Workers

6. What is the best method in your view to solve this problem?

Modern Machines

7. What would be the best possible addition to this shop?

Updated Profiling Machine, Lifting Crane

## Appendix F: Interview #2

WPI IQP 2016

TransNamib Rolling Stock Revival

Windhoek Repair Workshop Employee Survey

Interview #2

1. What is your position?

Technical Supervisor

2. What processes in the shop do you manage?

Electrical Repairs

3. What is the most common repair or job you carry out?

Traction Motor Repair, Lights, Bulbs, Engine Fan and Heater, Component Failures

4. What is the biggest problem that you see with the current process?

Outdated Machinery, Lack of Manpower

5. What is the biggest success that you see with the current process?

Design of Repair System

6. What is the best method in your view to solve this problem?

Modern Technology

7. What would be the best possible addition to this shop?

Full Machinery for Traction Motor Overhaul

## Appendix G: Interview #3

WPI IQP 2016

TransNamib Rolling Stock Revival

Windhoek Repair Workshop Employee Survey

Interview #3

1. What is your position?

Technical Supervisor

2. What processes in the shop do you manage?

Compressors, Fans, Brakes, Running Maintenance

3. What is the most common repair or job you carry out?

Brake Valves, previously compressors and fans

4. What is the biggest problem that you see with the current process?

Spare Parts, Lack of Manpower and Lack of Space

5. What is the biggest success that you see with the current process?

Efficient Brake Shop System

6. What is the best method in your view to solve this problem?

More Supplies, Higher Quality Parts

7. What would be the best possible addition to this shop?

Test Stand for Compressors, Laser Alignment for Engine Placement



## Appendix H: Interview #4

WPI IQP 2016

TransNamib Rolling Stock Revival

Windhoek Repair Workshop Employee Survey

Interview #4

1. What is your position?

Technical Supervisor

2. What processes in the shop do you manage?

Engines and Regular Inspections

3. What is the most common repair or job you carry out?

Cylinder Casings

4. What is the biggest problem that you see with the current process?

Spare Parts, Lack of Manpower

5. What is the biggest success that you see with the current process?

Regular Maintenance

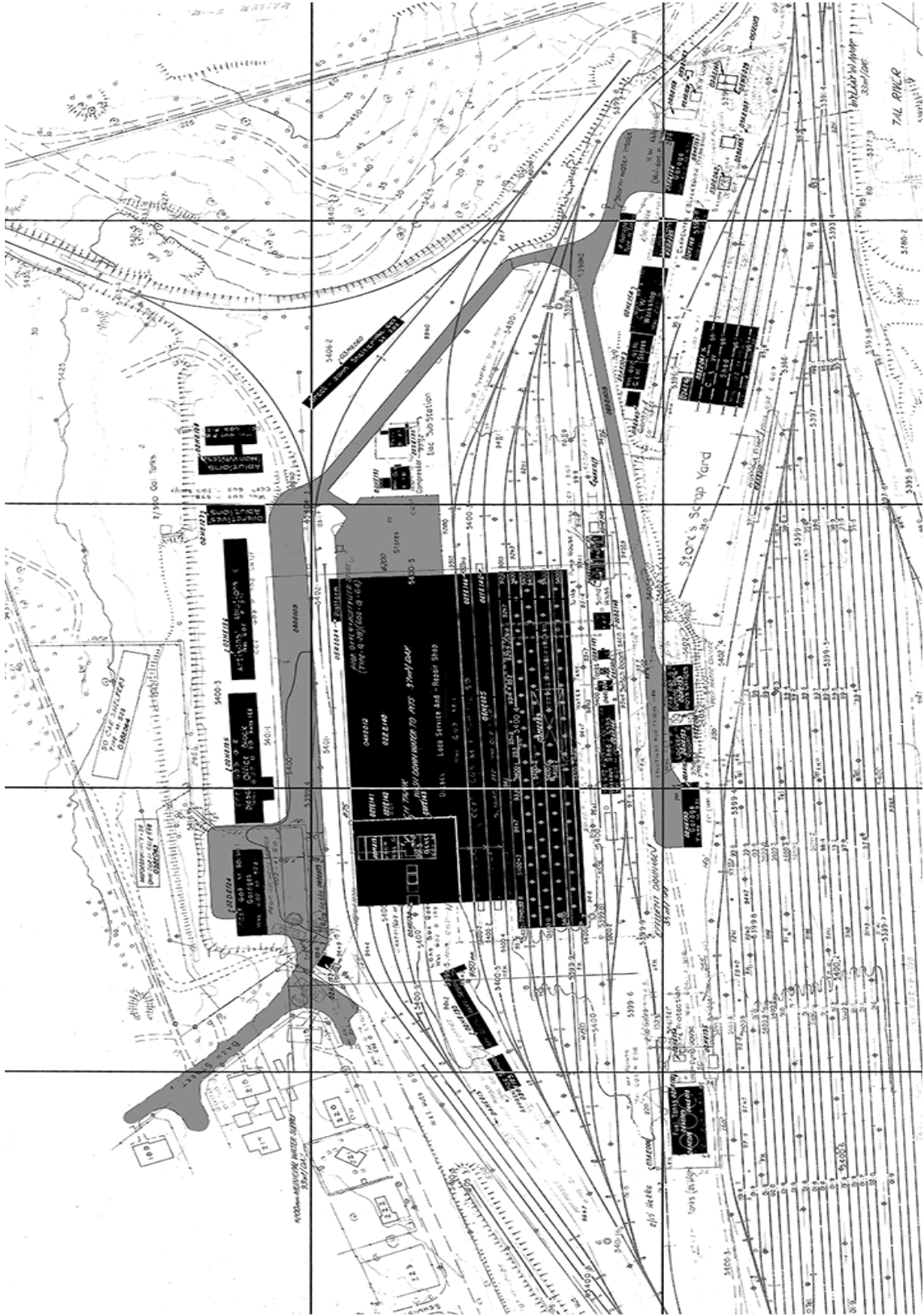
6. What is the best method in your view to solve this problem?

More Supplies and Skilled Workers

7. What would be the best possible addition to this shop?

Improved Crack Testing Machine

# Appendix I: Windhoek Repair Workshop Designs

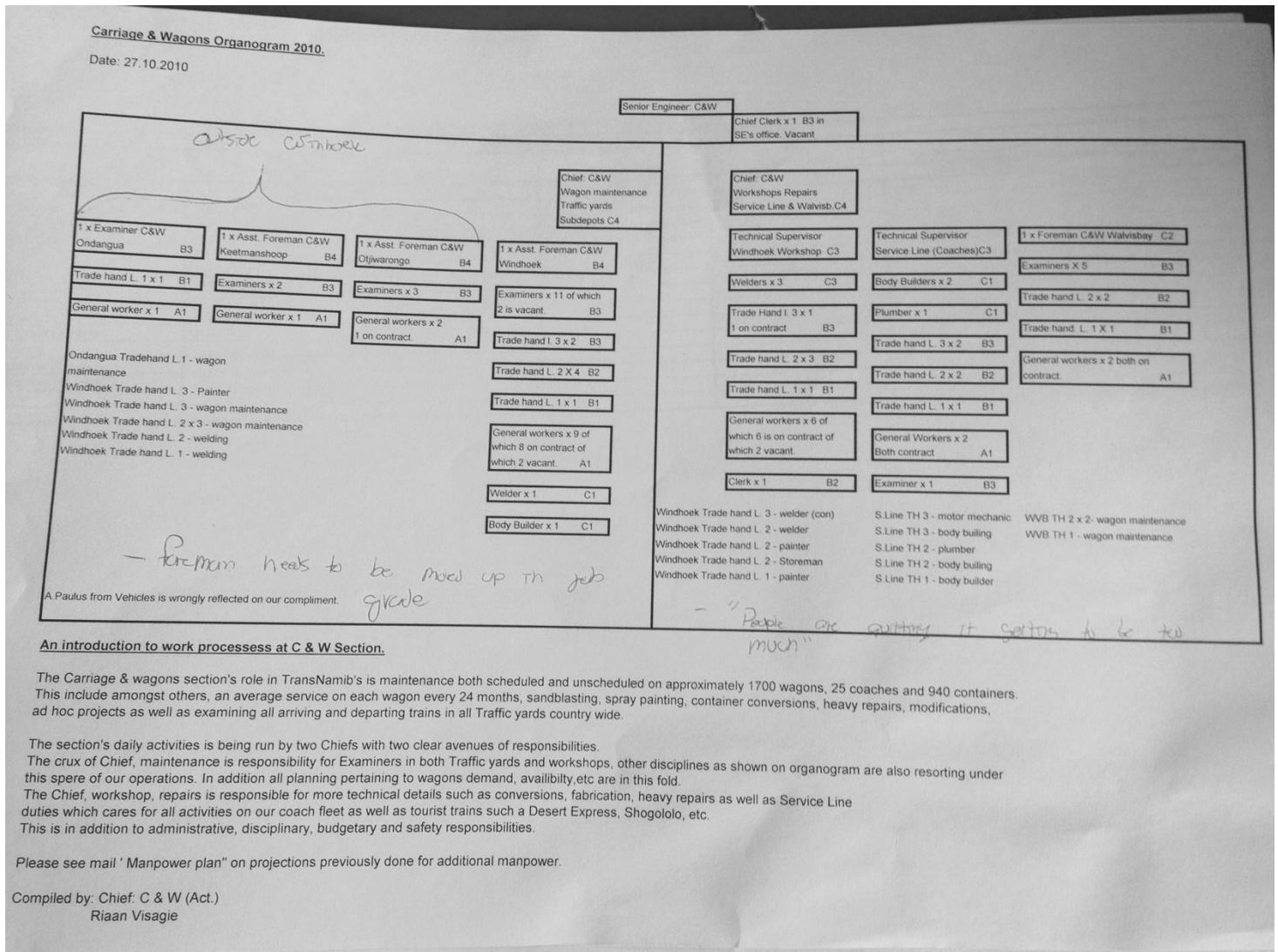


# Appendix J: Usakos Repair Workshop Designs





# Appendix K: Windhoek Rolling Stock Organogram



# Appendix L: Windhoek Locomotive Technical Supervisor Responsibilities

TRANSNAMIB HOLDINGS LOCOMOTIVE DEPOT WINDHOEK: PERSONNEL ROSTER  
M. Herunga 2268 KHR 02 250, WVB 06 532, OTT 07 244, OND 11 213  
DATE: 2012/...../.....

601 von Hatten 2137 MECHANICAL	602 Endyala 2237 BACK SHOP	603 Boucher 2134 RUNNING SHED	604 Boucher 2134 PLATFORM	605 Kandinda 2036/2538 Lab & Effluent	606 Ngujinazo 2346 TRAINING
Eng. Bay	Small Parts	Shed Personnel	Brake Shop	Water Test	App. School
Cyl. Bay	Electrical Above Deck	Shed Rosters	Expressor Shop	Oil Test	App. Training
Fuel Shop	T. Motor Bay	Loco Wash & Polish	Fan Shop	Effluent Plant	T. H. Training
Turbo Shop	Generator Bay	Bulk Fuel & Issue	Shift & Trips		Artisan Training
Cylo Bay	Battery Shop	Sand Room & Scrap	Bulk Fuel & Issue		Refresher Coures
O + W Pumps	Cont. Fault finding	Hardstand Clean	Personnel Roster		Projects
Mechanical Above Deck	Power Fault Finding		Daily Stop List		RFO's
Millwright	Radiators & Oil Coolers		Shift Roster		Tool Room
Availability Forms	No 2 End		Platform Clean		Tool Store
Bulk Oil					Load Box
Ablution Blocks					
Compressor Room					

# Appendix M: TransNamib Locomotive Fleet

## LOCOMOTIVES ASSET REGISTER AS ON 3 December 2015 33 - 400 CLASS

LOCO'S IN SERVICE		LOCO'S STABLED	LOCO'S STABLED	WRECK LOCO'S	LOCO'S SCRAPPED
33-002		402 Fire			467
33-013	464	412 Exp,wires burnt			430
33-017	465	446 Exp,turbo,fan			444 11/11/2009
33-030	468	447 Exp,turbo,fan	427		484 11/11/2009
33-041			435		
33-051	472	470 Exp,turbo,fan			405 WDU
33-059	473	474 Collision	443		494 ADI
413		480 Collision	508		
416					509 11/11/2009
417	479				507 KZB
432		502 MG,exp, turbo			
437	483	503 TM cables			
441	486	504 Exp			
442	489	505 Exp			
445	493	510 Cyl C/O			
457	501	431 Collision			
459	506	476 Collision KFD			
460					
463	511				
TOTAL: 32		TOTAL: 18		TOTAL:	TOTAL: 6

33-006

## 32 - 200 CLASS

LOCO'S IN SERVICE		LOCO'S STABLED	LOCO'S STABLED	WRECK LOCO'S	LOCO'S SCRAPPED
		205 Eng, exp	206		
		207 Exp			
		208 Fire			
TOTAL: 0		TOTAL: 4		TOTAL:	TOTAL: 0

## 34 - 200 & 35-400 CLASS LEASE LOCOMOTIVES

LOCO'S IN SERVICE		LOCO'S STABLED	LOCO'S STABLED	WRECK LOCO'S	LOCO'S SCRAPPED
1001	34-232				
1002	34-240				
1003	34-249				
1004	35-008				
34-225	35-489				
34-226	35-438				
	35-491				
TOTAL: 13		TOTAL: 0		TOTAL: 0	TOTAL:

35-609

## SDD6

LOCO'S IN SERVICE		LOCO'S STABLED	LOCO'S STABLED	WRECK LOCO'S	LOCO'S SCRAPPED
SDD 2		SDD 1		SDD 13 USS Coll	
		SDD 5		SDD 11 Coll WNL	
		SDD 7		SDD 4 ADI	
		SDD 8		SDD 6 ADI	
		SDD 10		SDD 14 Fire KZB	
		SDD 12		SDD 16 Fire KZB	
		SDD 15			
SDD 9		SDD 17			
	2	SDD 3	9		
				TOTAL: 6	TOTAL: 0

## CHANGES 35-491 into service

### DMU

DMU 0001
TOTAL: 1

	Active	Stable/Wreck	TOTAL
TOTAL 400:	32	18	50
TOTAL 200:	0	4	4
TOTAL 34 & 35	13	0	13
TOTAL SDD6:	2	15	17
TOTAL DMU:	1	0	1
<b>TOTAL:</b>	<b>48</b>	<b>37</b>	<b>85</b>

## REBUILT LOCO'S

OLD NO.	NEW NO.
453	501
434 (WRECK)	502
414	503
475 (WRECK)	504
422 (WRECK)	505
455	506
419	507
407	508
425 (WRECK)	509
478 (WRECK)	510