

# Optimization of Transformer Workshops

Focused on the Material Handling System and Finalization of the Facility Layout

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Rotek Engineering Power Distribution Services

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## Executive Summary

The Power Distribution Services (PDS) Department of Rotek Engineering is located in Germiston, Gauteng. PDS specializes in the repair of medium to large transformers. PDS can refurbish most known transformer brands including Ferranti, GEC, ABB, Asea, Toshiba, Bhaharat Electricals, Wilson, English Electric etc. PDS is aiming and expecting to increase the throughput in the workshops within the next five years. However, it is believed that the current facility layout and the current material handling system would not be able to cope with the influx of transformers.

This project will aim to optimize the PDS workshops by finalizing the facility layout and by developing a set material handling system. This will be achieved through the use of various relevant industrial engineering methods, tools and problem solving techniques. This report will show the author's recommendation to PDS.

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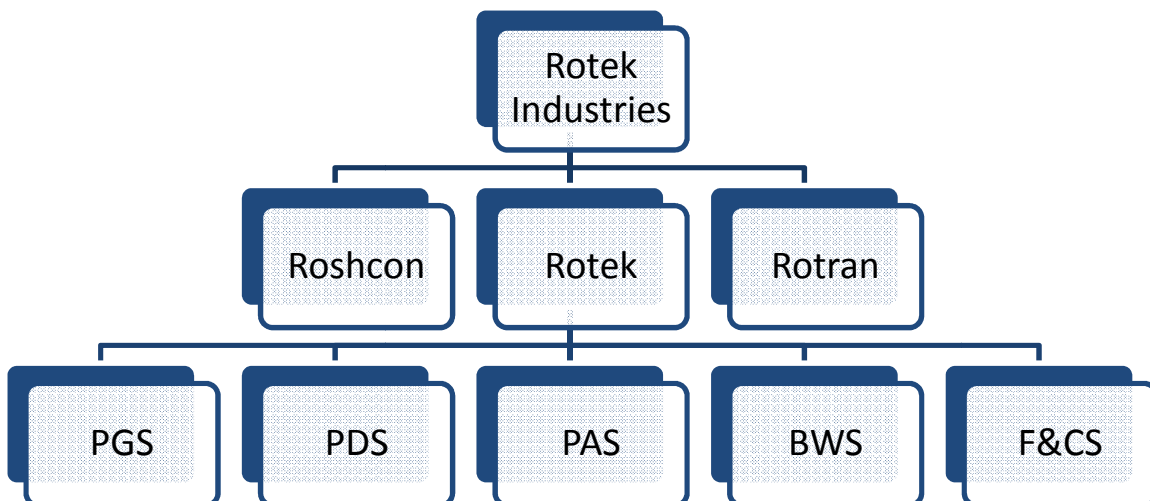
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## 1. Background and Information

### 1.1. Company Background

Rotek Engineering forms a part of the Rotek Group along with Roshcon and Rotran. The Rotek Group was formed in 1989, when assets and operations of Eskom’s central maintenance services (est. 1913) were transferred into an independent holding company, namely Rotek Industries (Proprietary) Limited.

This project will be based in the Power Distribution Services (PDS) which form a part of Rotek Engineering. PDS repairs and, or overhauls small, medium and large transformers in their workshops. PDS also does repair and maintenance work on site, however this aspect of PDS will not be evaluated in this project.



**Figure 1: Rotek Industries Hierarchical Breakdown**

This project will address the problems of the layouts of the current workshops as well as the current material handling system.

Rotek Engineering’s PDS department prides itself in delivering quality services to customers in a timely manner; however this can only be achieved through the efficient use of space in the workshop and with a structured material handling system. Proposed alternatives will address perceived areas that are preventing PDS from achieving their desired overall throughput.

## 1.2.Transformers

Transformers are electrical devices that are used to change the voltage in an electric circuit. A transformer works on the principle of inductance. An alternating electric current entering the transformer through the primary coil creates a magnetic field within the iron core. The strength of the electric current determines the strength of the magnetic field.

When the magnetic field is created in the iron core the reverse effect happens in the secondary coil at the other side of the core. An electric current is created in the secondary coil by the vibrating magnetic field within the core.

The transformer is used to increase or decrease the voltage within the system. A step-up transformer increases the voltage in a circuit and a step down transformer decreases the voltage.

Transformers are used every day. Most household appliances operate at a lower voltage. It is however easier to transmit electric current in high voltage form. Therefore it is important to install transformers near the point where electric current enters the household circuit.

For the purposes of this project it can be assumed that a transformer consists of:

1. One tank
2. One active part (One core)
3. Eight bushings
4. Three tap changers
5. Nine windings
6. Various other parts such as radiators.

### 1.3.Problem Background

Rotek Engineering wants to increase the capacity in the Power Distribution Services (PDS) department. Currently PDS is running at 54 transformers per year. It has been determined that at present they can only do 88 transformers per year, however it is expected that PDS will need to be able to have a capacity of 130 transformers per year within the next 5 years.

Currently PDS has two main workshops for medium and large transformers. They also have workshops for specialized parts that include windings, painting, tank and parts, bushings, tap changers.

With the current layout and material handling system the workshops can only do 88 transformers per year due to various constraints. The main constraints however is in Tank and Parts, this is the area where repairs are done to the tanks and to other external parts, and in the Paint Bay.

PDS has already done some research and has a couple of alternative facility layouts. However these layouts are incomplete. They do not state exactly how many work areas are needed for every process. Processes for the transformers include un-tanking, inspection, repair and disassembly, final assembly, vapour phase, tanking, vacuum and oil testing and final testing. This needs to be determined for the medium and large transformer departments.

Currently material handling is unstructured and is only done on request. This causes major delays in the movement of parts between departments. It is expected that the lack of planning and foresight in the current system will cause such delays that it will not be possible to get to the capacity of 130 transformers per year.

It is also requested that it be determined what new material handling equipment will be needed to increase the capacity of PDS. It is clear that the current layout and material handling system is insufficient for the developments within Power Distribution services.

## 2. Problem Statement

The Power Distribution Department (PDS) of Rotek Engineering is not capable to cope with an increased throughput expected and desired by management within the next five years. It is expected that the transformer throughput will first increase to 88 transformers per year and then to 130 transformers per year, within the next five years. PDS needs to finalize the plans for a workshop overhaul which will include new facility planning and a material handling system. The main question that Rotek would like answered is “Does the company need to buy/rent the Rollfab facility for an extra paint bay, and tank and parts repair workshop?”

## 3. Project Aim

The aim of this project is to first finalize the alternative layouts and make a recommendation, then to develop an improved material handling system for the transformer workshops in the facility.

- Improve the current layout, through various alternatives.
- Improve the current material handling system, combined with the layout alternatives.
- Optimize the facility to accommodate 130 transformers per year within the next 5 years.
- Determine the costs of the various alternatives.
- Decide which alternative will suit Power Distribution services the most.

## 4. Project Scope

The purpose of this project is to develop an improved layout and material handling system for Power Distribution services. The improved layout and material handling system should take into account the increase in throughput from 54 transformers per year to 130 transformers per year within the next 5 years. The facility layout should be safe, structured and be conducive to the flow of materials. The material handling system should be efficient, structured and as cost effective as possible.

## 5. Deliverables

This project's deliverables are used to help with the optimization of transformer workshops. Especially with regard to facility planning and material handling systems. The deliverables are as follows:

- Operation Analysis: What, Why, How, Who, Where, When?
- Analysing the current facility
- Analysing the given alternatives
- Determine the amount of bays needed
- Determine the material flows for the current facility
- Determine the material flows for the given alternatives
- Determine the material handling options
- Determine a final recommendation that combines the facility, material flow and the material handling system

## 6. Literature Review

### 6.1. Overview

The literature review for this project will be essential to the gathering of important information about methods, tools and techniques that will be relevant and useful to this project. The analysis of the data collected will provide a better understanding of the problem facing Rotek Engineering PDS. Using these methods, tools and techniques a solution to Rotek Engineering PDS problem will be developed and recommended. The goal is to develop a solution from various industrial engineering techniques that will finalize the facility layout and improve the current material handling system.

Rotek Engineering Power Distribution Services is expecting a higher throughput within their transformer workshops. However it has been determined that the current layout of the facility and the current material handling system would not be able to run at the expected capacity. It is clear that the company will greatly benefit from the increase in throughput and the company wishes to embrace and expand on these expectations.

Information was and will be gathered from the following sources:

- Student observations
- The University project leader
- The company mentor
- Discussions with employees at PDS
- Textbooks
- Journals
- Internet
- Previous studies
- Similar projects

## 6.2. Facilities Planning

The modern day facility plan is implemented to increase a company's supply chain excellence. The supply chain excellence process can be explained in six steps; Business as usual, link excellence, visibility, collaboration, synthesis and velocity.

- **Business as usual**  
This step is when a company focuses on maximizing the individual functions of the supply chain. The different departments should strive to be the best department in the company. Therefore in this step organizational effectiveness is not the emphasis.
- **Link excellence**  
After the "Business as usual step" the company should strive to function as one. To achieve this, the company needs to tear down any internal boundaries within the company. From this step the company will start its never ending quest of continuous improvement. Strategic and tactical initiatives at department, plant and link level for design and systems need to be implemented.
- **Visibility**  
This particular step brings to light any and all links within the supply chain. With all the links available for scrutiny it will decrease the amount of supply chain surprises significantly. This step provides the information links needed to understand the ongoing status.
- **Collaboration**  
To ensure the company knows how to meet the demands of the marketplace in the best way, collaboration within the company will be needed. The company needs to optimize the supply chain to maximize customer satisfaction while minimizing inventory. This can be achieved through the use and application of technology and partnerships.
- **Synthesis**  
This is the unification of all the supply chain links to form a whole. Results of synthesis are increased return on assets, improved customer satisfaction, reduced costs and an integrated supply chain. Synthesis is a long and continuous process.
- **Velocity**  
Synthesis at great speed is velocity. With the improvement of technology and the availability of that technology throughout the world the speed of business has increased dramatically within the global economy. Velocity creates multilevel global networks to meet the demands set by the global economy.

Facilities planning must be done with the supply chain in mind to maintain a competitive advantage. Customer satisfaction should be the primary objective of facilities planning. If this objective is kept in mind, all the other objectives will follow the drive of the company, namely revenues and profits from customers. The main objectives of facilities planning are to:

- Increase customer satisfaction by meeting customer needs.
- Increase the return on assets by maximizing inventory turns, maximizing employee participation and maximizing continuous improvement.
- Quick customer response.
- Reduce costs and increase profitability.
- Integrate the supply chain.
- Support the company's vision.
- Effectively utilize people, equipment, space and energy.
- Maximize the return on investments on all capital expenditures.
- Be adaptable and promote ease of maintenance.
- Improve employee safety and job satisfaction.
- Assure sustainability and resilience.

The process of facilities planning follows a set of steps. These steps may differ slightly from company to company but does have similarities. Here is an example of these steps.

1. Establish goals

The first step in a facilities planning project is to establish clear, specific objectives to be achieved. These are the expectations that the company has with regard to their facility.

2. Collect and analyze facts

During this step it is important to gain as much data as possible. This includes existing conditions, people projections, space available, space standards and codes. These all form part of the information to establish an accurate essential knowledge base.

3. Uncover and test concepts

Concepts are the means to an end. Concepts are used to determine the best way to achieve the company's goals. It is important to brainstorm with various employees of the company to gain knowledge and ideas to achieve the company goals.

4. Determine needs

Every project within a company asks the following "How much will it cost?" The four components of cost are:

Quality – The project budget

Space – The space list

Support systems – Utility matrix

Schedule – The project schedule

## 5. State the solution

This final step states the advised solution to achieve all the goals set by the company. The solution should be clear and detailed. The company should know what to expect when implementing this solution and should be able to see how they will implement the solution.

Flow systems are an integral part of the facilities planning process. The flow is the movement of goods, materials, energy, information, equipment and/or people. This project will focus on the discrete flow processes. Discrete flow processes show the movement of discrete items throughout the facility. Continuous flow processes differs from a discrete flow process in that the products continuously move through successive production states for example the flow of electrical current.

Discrete flow system processes can be categorized according to the stages of the supply, manufacture and distribution cycles. These categories are material management system, material flow system and physical distribution system. The three categories combine to form one overall flow system referred to as a logistics system.

### 1. Materials Management System

The flow of materials into a facility is the defining factor for a process to be categorized as part of the material management system. Subjects of this system include materials, parts and supplies purchased by a company and required for production or the implementation of a service. Resources of the materials management system include:

- Production control and purchasing functions
- Vendors
- The material handling equipment especially the transportation equipment required to move the materials, parts and supplies
- Receiving, storage and accounting functions

### 2. Material Flow System

This project will mainly focus on the material flow system within the company. If materials, parts and supplies move within the facility the process can be categorized as part of the material flow system. The subjects of this system are the materials, parts and supplies used by the company to manufacture products, components or to do the service within the facility. The resources of a material flow system are the following:

- The production control and quality control departments
- The manufacturing, assembly and storage departments
- The material handling equipment needed to move materials, parts and supplies throughout the facility
- The factory warehouse

### 3. Physical Distribution System

The process of products that flow from a facility is to be categorized as part of the physical distribution system. These processes form part of the distribution of finished goods produced by the company. Resources include:

- The customer
- The sales and accounting departments and warehouses
- The material handling and transportation equipment required to move the finished product
- The distributors of the finished product

## 6.3. Line Balancing

Line balancing is of general interest to academics as well as practitioners. Implementing line balancing tries to achieve a material flow balance consistent with dictates of Just-In-Time manufacturing concepts. The main objectives of line balancing are to maximize the capacity utilization of the line and minimize the flow time.

Line balancing develops a system with the ideal number of workers to be assigned to a workstation or assembly line. Jacobs et al (2009) defines assembly line balancing as the “problem of assigning all the tasks to a series of workstations so that each workstation has no more than can be done in the workstation cycle time, and so that idle time across all workstations are minimized.”

**The following steps are for performing line balancing by Jacobs et al (2009):**

1. Draw a precedence diagram. This diagram should depict the order in which tasks must be performed in the facility.
2. Determine the workstation cycle time (C):

$$C = \frac{\text{Production time per day}}{\text{Required output per day}}$$

3. Determine the minimum number of workstations required (N):

$$N = \frac{\text{Sum of the tasks}}{\text{Cycle time}}$$

4. Determine the primary rules to which tasks are to be assigned to workstations
5. Assign tasks, one at a time, to a workstation until the sum of task times are equal to the workstation cycle time. Repeat this process for all the workstations until there are no more tasks to assign.
6. Evaluate the efficiency of the balance:

$$\text{Efficiency} = \frac{\text{Sum of the task times}}{\text{Cycle time}}$$

7. Rebalance the line using a different decision rule, if the efficiency is unsatisfactory.

## 6.4. Queuing Theory

Waiting in a queue is a regular occurrence for everyone. The management of these queues are therefore an important part of operations management. The queuing system consist of three major components, namely The source population and the way customers or items arrive at the system, the servicing system and the condition of the customers exiting the system.

Customer or item arrivals can be defined as a finite or infinite population. A finite population refers to the limited-size customer or item pool that will use the service and form a line. It is important to note that when a customer leaves the system that the customer or item pool reduces by one. In a system with an infinite population the population is not influenced by the addition or subtraction of customers or items.

The arrival rate of units can be described in many different ways. The arrival rate is determined by the number of units per period. A constant arrival rate is periodic and easy to determine. The rate will be exactly the same between successive arrivals. However, it is much more common to see a variable arrival rate or distribution. We typically assume that the arrivals per time unit is Poisson distributed.

There are several other arrival characteristics such as the arrival patterns, size and number of arrival units and the degree of patience. Factors that affect the queuing system include the following: Length, the number of lines and queue discipline.

Once a customer of item is serviced there are two possibilities. The first is that the customer may return to the source population and immediately become a competing candidate for service again or the second being that there is a low probability of re-service.

## 6.5. Lean Manufacturing

The primary purpose of lean manufacturing is to improve productivity and to reduce cost. It does not only cover manufacturing costs, but also sales, administrative and capital costs. It is especially important to put emphasis on cutting waste, decreasing cost and increasing efficiency during times of lower growth.

Toyota's past president, Fujio Cho, defined waste as "Anything other than the minimum amount of equipment, materials, parts and workers which are absolutely essential to production." Lean manufacturing expanded on this definition with seven prominent types of waste that need to be eliminated from the supply chain:

1. Waste from overproduction
2. Waste of waiting time
3. Transportation waste
4. Inventory waste
5. Processing waste
6. Waste of motion
7. Waste from product defects

Lean manufacturing requires the plant layout to be designed in a manner that would be conducive to balanced work flow with a minimum amount of work-in-process inventory.

## 6.6. Just-In-Time Manufacturing

Just-In-Time manufacturing is very similar and frequently overlaps with Lean manufacturing principles. The same categories of waste are used in Just-In-Time manufacturing. Standard and Davis state that "Just-In-Time means having the right part at the right place in the right amount of the right material, in the right condition, at the right place, at the right time, in the right position, in the right sequence and for the right costs, by using the right method.

Looking at JIT philosophy we categorize these methods into five elements:

1. Visibility
2. Simplicity
3. Flexibility
4. Standardization
5. Organization

At the root of JIT philosophy is the need to decrease or completely eliminate waste. The most common sources of waste in a manufacturing facility are:

- Equipment
- Inventories
- Space
- Time
- Labour
- Time
- Handling
- Transportation
- Paperwork

JIT philosophy impacts a company in various ways such as:

- Reduction of inventories  
Inventories will be reduced if products are produced, purchased and delivered in small lots, the production schedule is levelled, quality control procedures are improved or if production, material handling and transportation equipment are maintained adequately. If inventories can be reduced the space requirements will also be reduced and smaller loads are moved and stored, it will also reduce the storage requirements of the facility.
- Deliveries to points of use  
If products are delivered to the points where they are used stock-outs at the consuming processes will be avoided. To enable the delivery of the products to the points of use the company needs to have multiple receiving docks in the facility and needs a decentralized storage policy.
- Quality at the Source  
Processes need to ensure quality. The supplying process needs to view the consuming process as its customer. In that way it should be viewed that the supplying process needs to meet the customer needs. These views should be throughout the process line. It can therefore be said that the process should deliver parts to the next process in the same level of quality that it received it from the preceding process.
- Better communication, line balancing and multifunctional workers.  
The communication policy between processes, departments and even workshops will change and visibility within the facility will increase. The JIT policy also requires workers to do various multifunctional tasks. The expectation will be that a worker does not specialize in one single function and will increase his/her work rate by performing multiple tasks.

Companies that use the JIT system use contracting to ensure safe, consistent and fast service. This is very important because the JIT system relies on quick service rather than the build-up of stock or inventory. Transportation delays decrease production, increase inventory costs and disrupts the operations, which negates all the objectives of the JIT system.

## 6.7. Kanban Systems

Kanban means “signal” and commonly uses cards to signal the supplying workstation that its consuming workstation requests more parts. The kanban system is usually used when a supplying workstation operates at a faster rate than the consuming workstation. If production does not stop a build up of parts will take place after the supplying workstation. This will overwhelm the consuming workstation. Therefore it makes sense to stop production in the supplying workstation temporarily to ensure the consuming workstation can catch up with the required work needed.

Kanban control systems uses a signalling device to regulate the Just-In-Time(JIT) flows within the system. The kanban pull approach can be used not only within a manufacturing facility but also between manufacturing facilities and between manufacturers and external suppliers. Figure 2 shows how kanban systems help maintain inventory levels. A signal is sent to produce and deliver new materials to be consumed. This ensures that materials that are consumed in the process are replenished in a structured and timely manner.

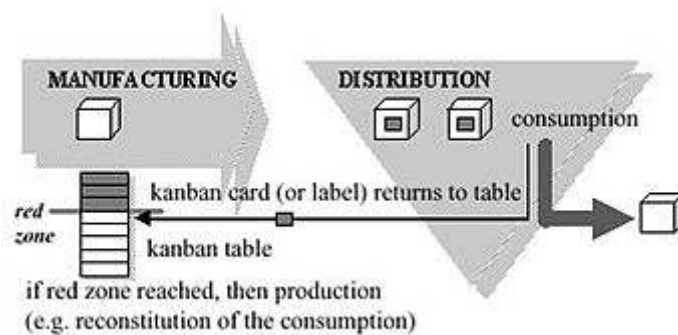


Figure 2: Kanban System

To determine the optimum kanban control system it must first be determined how many kanban cards will be needed.

$$k = \frac{DL(1 + S)}{C}$$

$k =$  Number of Kanban cards

$D =$  Average number of units demanded per period

$L =$  Lead time to replenish an order

$S =$  Safety stock expressed as a percentage of the demand during the lead time

$C =$  Container size or batch size

The kanban system does not produce a system with no inventory it controls the amount of material that can be in process at a time.

## 6.8. Housekeeping

Good housekeeping means that only the necessary items are kept in a work area. There should be a specified place for everything and everything should be ready to use at any time. This means that the item should be clean and in a constant state at all times. It should be the employee's responsibility to clean his own tools and his working environment. Good housekeeping improves service processes, improves the attitude of the employees, increases the development of continuous improvement and improves the customers' perception that they are receiving better service.

The 5-S methodology of housekeeping is based on 5 Japanese acronyms:

- Seiri – Organization
- Seiton – Neatness
- Seiso – Cleaning
- Seiketsu – Standardization
- Shitsuke – Discipline

Housekeeping is a value driven business model that can be seen as the initiating point within lean manufacturing. The primary goal of housekeeping is to develop a safe and healthy working environment where productivity can be increased. The benefits of housekeeping, especially with the 5-S methodology in mind, include:

- Reduced workload and human errors
- Simplified processes
- Maximized effectiveness
- Increased quality
- Enhanced level of worker morale
- Healthier and safer work environment
- High level of autonomy

## 6.9. Material Handling Systems

The material handling system is an integral component of overall facilities design. The design of the layout of a facility is inseparable from the material handling system of the facility. These facility layout and material handling system needs to work hand-in-hand to ensure a well designed facility is developed.

In a typical industrial facility, material handling accounts for 25% of all the employees, 55% of all the factory space and 87% of production time. Material handling is also responsible for a high percentage of the total cost of manufacturing. The ideal goal would be to eliminate material handling completely, however in the practical sense this is not possible. Therefore the goal of a material handling system is to reduce the material handling as much as possible. The Material Handling Institute of America defines material handling as “The art and science associated with the movement, storage, control and protection of goods and materials throughout the process of their manufacture, distribution, consumption and disposal.”

The conventional view of material handling focuses solely on the movement of material from one location to another, usually within the company boundaries. The contemporary view of material handling expands the focus of the movement throughout the factory, warehouse or workshop; an effort is made to develop an integrated material handling plan. The progressive view about material handling entails a total system view. This includes the movement of material or items from the suppliers, within the facility, to the distributors or distributing facility and the distribution of finished goods to the final customer.

The College-Industry Council on Material Handling education recognizes ten material handling principles, they are the following:

1. **Planning Principle**  
This is a recommended guide that is created in advance of the implementation of the system. This plan should show which materials are moved, when and where to the materials should be moved and the method of movement.
2. **Standardization Principle**  
The methods and equipment that are used should be standardized. The material handling process should vary less and should not be customized on a regular basis.
3. **Work Principle**  
Material flow times the distances moved are the measure of work. This kind of work should be minimized as much as possible.
4. **Ergonomic Principle**  
The work being done and the working conditions should be adapted to suit the abilities of the worker performing the task. This will increase the productivity.
5. **Unit Load Principle**  
This principle creates the opportunity to move or store one or more items at the same time. This reduces the amount of material handling time considerably.

6. **Space Utilization Principle**  
Use the entire space. This includes the vertical. Space is a three-dimensional element, therefore is counted as cubic space.
7. **System's principle**  
A system is a set of interacting/independent entities that form a whole. This should be taken into account when designing a material handling system.
8. **Automation Principle**  
Technology is always improving, with automation the material handling is done with electromechanical devices, electronics and computer based systems. This decreased the amount of mistakes made and increases the safety within the facility.
9. **Environmental Principle**  
Within the global economy there is a growing trend to be environmentally conscious. This means to do what is possible not to waste natural resources and to predict and eliminate the possible negative effects of the company's actions on the environment.
10. **Life-Cycle Cost Principle**  
These are the costs involved from the very first monetary value and include all cash flows that will occur during the plan, project or procedure. Until that method/equipment is replaced.

When designing a material handling system it is always good to aim for the theoretical ideal system. Develop a system as close to the ideal system as possible. There is a recommended six-step design process for the design of a material handling system, it is as follows:

1. Define the objectives and scope for the material handling system.
2. Analyze the requirements for moving, storing, protecting and controlling material.
3. Generate alternative designs for meeting material handling system requirements.
4. Evaluate alternative material handling system designs.
5. Select the preferred design for moving, storing protecting and controlling material.
6. Implement the preferred design.

## 6.10. Material Handling Equipment

### 6.10.1. Jib cranes

Jib cranes are cranes that have a horizontal boom that supports a moveable hoist. Jib cranes can be fixed to a wall or to a floor mounted pillar. These cranes are generally used in industrial facilities. The jip can swing in an arc to give higher lateral mobility. Jib cranes are great for assembling or disassembling large items within a workstation.

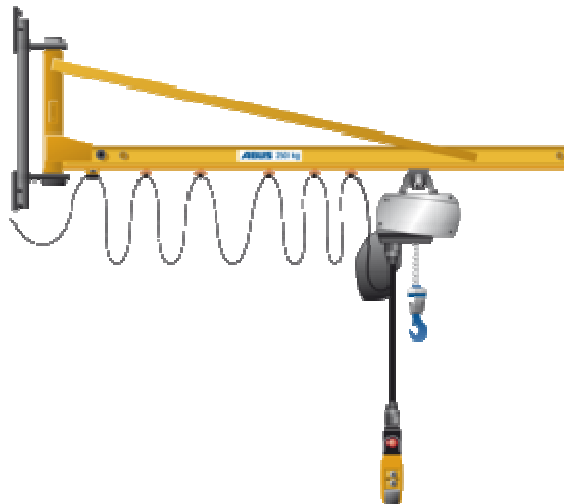


Figure 3: Jib Crane

### 6.10.2. Bridge cranes

A bridge crane has a hook-and-line mechanism that runs along a horizontal beam. This beam in turn runs on two separated rails. The crane is run by a trained employee either via remote or direct control. Bridge cranes are used in rectangular factory buildings with rails on the elongated walls. The cranes usually consist of either a single or double beam construction. Double beam bridge crane systems are usually used for the movement of heavier items. Bridge cranes can be used to move objects as small as 50kg up to 600 tons or more



Figure 4: Bridge Cranes

### 6.10.3. A-frame cranes

A frame cranes are used in a similar way to the bridge crane. The hoisting mechanism is set onto a beam. This beam is then supported by two A-frame upright support pillars. Underneath the support pillars are wheels; this allows the entire crane to move where needed, if the space allows it. A-frame cranes are also known as gantry cranes.

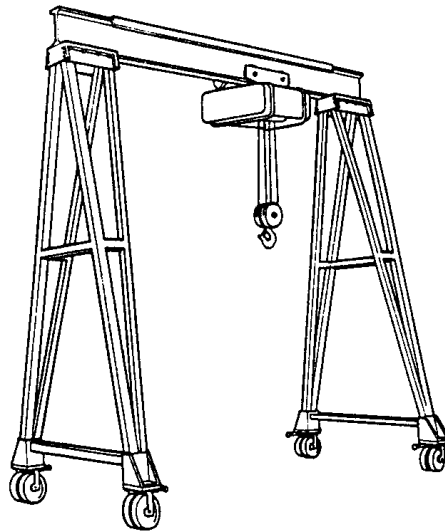


Figure 5: A-frame Crane

### 6.10.4. Forklifts

Forklifts are powered industrial trucks used to lift and transport material and goods throughout facilities. The forklift is integral in the modern day material handling system in manufacturing and warehousing operations. In general attachments can easily be added or created to the forklift to carry specialized materials or goods.



Figure 6: Forklifts

### 6.10.5. Trucks

Trucks in the industrial sense are generally used to carry materials to and from facilities. These trucks can carry heavy loads over long distances. Companies can buy their own trucks, rent trucks or use trucking companies to carry the necessary loads form them.



Figure 7: A transformer being transported via truck

### 6.10.6. Bogies

Bogies are wheeled wagons or trolleys. It consists of a chassis or framework, carrying wheels attached to a vehicle. Bogies can be moved by itself only on wheels or on a track similar to a railroad track.



Figure 8: Bogie running on a railroad track

### 6.10.7. Hand Trucks

The hand truck is one of the simplest and most inexpensive types of material handling equipment. This L-shaped truck carries small loads over relatively short distances. Mechanically it is a base that runs on two, four or more wheels. The base is also connected to some form of pulling or pushing extension. The hand truck is moved manually by pushing on these extensions.



Figure 9: Hand Trucks

### 6.10.8. Air Cushion System

Floating turntables or floating transfer pallets can be used to move heavy objects throughout the facility. The transfer pallets can move separately or can be combined to accommodate heavier loads. For example, if you have three floating transfer pallets with a maximum load of 200 tons, the transfer pallets can each carry a single load of 200 tons or they could be connected to carry 600 tons of material. The air cushion system is easy to use and very manoeuvrable. Modern day air cushion systems can work on any reasonable stable floor area and can move on sloped areas. Air cushion systems work especially well in open floor plan facilities.



Figure 10: Air cushion transport system

## **6.11. Gantt Chart**

Gantt charts are used to assist with the planning of project schedules. It shows the starting and finishing dates for all the designated activities and the project. The project is broken down into manageable and functional activities that must be performed by using a work breakdown structure. All the activities are listed and scheduled on the Gantt chart. The Gantt chart also shows the status of activities and in turn the status of the project. The use of a Gantt chart helps to prevent a dramatic loss of time and falling behind schedule.

## **6.12. Methods, Tools and Techniques**

The information gathered from the observations within Rotek Engineering PDS has shown the need for the finalization of the facility layout and the need for an improvement in the material handling system and the material flow within the system. All of the above mentioned methods, tools and techniques will be integrated to develop a solution to the problem stated by the company. Special attention will be given to:

- Facilities planning
- Just-In-Time manufacturing
- Line balancing
- Material handling systems
- Material handling equipment

## 7. Current Transformer Workshop Data Gathering and Analysis

### 7.1. Overview

#### 7.1.1. Description of Departments

The following table lists the various departments and their functions in the PDS Facility. To facilitate in the design of relationship and space diagrams, various flows between these departments must be determined.

DEPARTMENT	DESCRIPTION
1. Receiving	Receiving and storing of incoming transformers
2. Shipping	Transformers awaiting dispatch
3. Tank and Parts	The Plinth is used to repair tanks, boilers and other external parts
4. Final Tank	Complete assembly of the transformer
5. Final Assembly	Complete assembly of the active part
6. Vapour Phase	Drying out of the active part
7. Testing	Various impulse tests of the complete transformer
8. Un-tanking	Removing the active part from the tank
9. Offices	Administration and supervisor seating
10. Painting	Painting of transformer parts
11. Windings	Clack operations, compression and welding occur
12. Inspection & Disassembly	Inspection and analysis of the incoming active part
13. Auxiliaries	Storage and modification of bushings and tap changers
14. Sling Store	Slings used by forklifts and cranes
15. Oil Depot	Oil stored from/for the transformer
16. Insulation Store	Insulation for windings
17. Tools & Equipment Store	Various tools used in and around the workshop

Table 1: Departmental Descriptions

#### 7.1.2. Main Areas of Concern

This project will be focussed on these six areas in the facility

- Medium transformer aisle  
This area handles all the parts concerning transformers that weigh less than 200 tons. This includes un-tanking, disassembly, testing, vapour phase, assembly and tanking.
- Large transformer aisle  
This area handles all the parts concerning transformers as large as 600 tons. This also includes un-tanking, disassembly, testing, vapour phase, assembly and tanking.

- Windings area  
This area concerns all the material handling that is involved with the repair or production of windings.
- Auxiliary areas  
The auxiliary areas are areas where the material handlings of smaller parts need to be considered. This area is divided into three areas namely bushings and CTs (Current Transformers), Tap changers and boiler shop areas.
- Receiving and dispatching  
Receiving and dispatching is involved with the material handling of materials needed in the repair of transformers. They are also involved with the dispatching of material handling equipment, such as forklifts and scotch carts.
- Tank and Parts  
This area's main focus is the storage and repair of parts or tanks that are un-used at that time. The material handling to and from this area is of great importance
- Paint Bay  
The paint bay is used to paint the tanks and external parts. A lot of material is moved to and from this area. Most of the material is moved to and from Tank and Parts.

## 7.2. Current Facility Layout

Current Layout

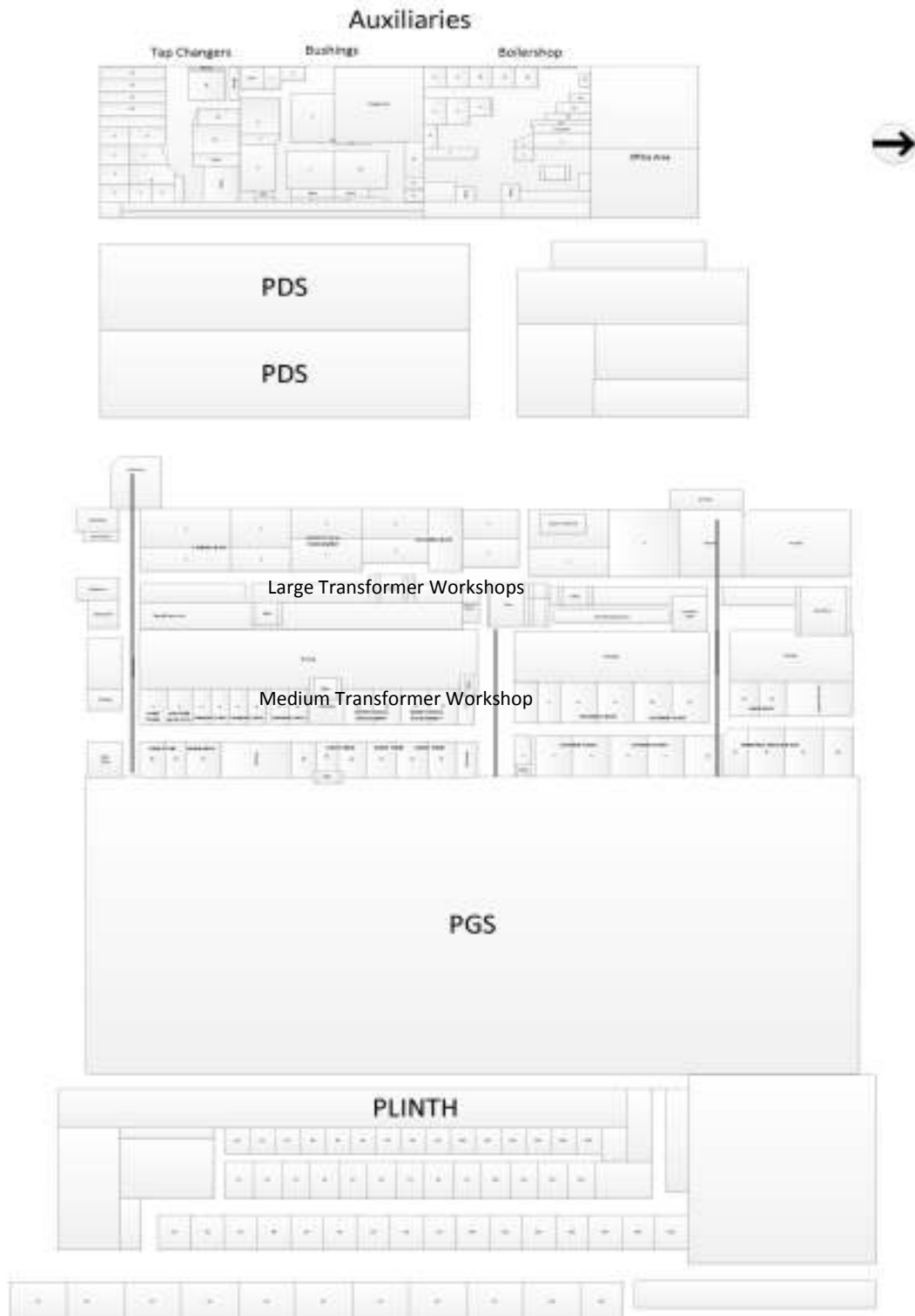


Figure 11: The current facility layout

### **7.3. General Comments Regarding the Material Handling In the Current Facility**

- The storage of tanks and tank and part alterations takes up space. This space could be used more efficiently as workspace.
- The current material handling system throughout the facility is inefficient. There is no structure and the workshops rely too much on the overhead bridge cranes.
- Currently the materials are not moved in a sequential manner. There is no logical flow of materials.
- The jib-cranes are currently being under-utilized. This is because of the habit of using the overhead bridge crane and the inefficient placement of transformers.
- The bays in the large transformer workshop are not standardized and the processes are not allocated to specific bays. This hinders planning and throughput.
- There are many fixed operational areas in the large transformer workshops. Areas such as the vapour phase, vacuum and oil testing area and the testing bay are all fixed.
- The current material handling in the tap changer workshop is slow and clumsy.
- A JIT or lean manufacturing system should be implemented to ensure that the auxiliary workshops can cope with increased throughput.
- The current amount of forklifts is not enough.
- There is no space in the plinth to do any alterations on tanks and parts.
- There seems to be a major issue with paperwork slowing down work inside the various workshops. The paperwork system needs to be updated and streamlined. However this does not form part of this particular project.

## 7.4.Current Material Handling Equipment

- Jib cranes
  - Medium transformer aisle  
They have ten 5 ton jib cranes in certain bays and five 1 ton jib cranes. Three of the 5 ton jib cranes are used in the un-tanking and tanking area. Three of the 1 ton jib cranes and three of the 5 ton jib cranes are used in the disassembly area. Four of the 5 ton jib cranes and two of the 1 ton jib cranes are used in the assembly area.
  - Large transformer aisle  
They have eight 5 ton jib cranes. Three jib cranes that can be used in the un-tanking and offloading area. Three jib cranes that can be used in the assembly area. There are two jib cranes that can be used in the tanking area.
- Bridge cranes
  - Large transformer aisle  
In the 600 ton area there are two 300 ton bridge cranes that are used to move heavy materials and parts. They are also used in the offloading of transformers. If a transformer or a part heavier than 300 tons needs to be moved, the two 300 ton bridge cranes are combined.
  - Medium transformer aisle  
A 75 ton bridge crane is used at the receiving, tanking and un-tanking area. This bridge crane is used for the heavier loads. If the load is larger than 75 tons, loading and offloading is done with a 200 ton bridge crane. There is also a 20 ton bridge crane that is used for smaller loads that need to be transported quicker.
  - Winding aisle  
There are two 15 ton bridge cranes for general use with specific focus on heavier materials and parts. There is also one 2 ton bridge crane that is used for smaller materials and parts.
  - Bushing aisle  
There are three 2 ton bridge cranes for the general movement of bushings, insulators or CTs

- Boiler shop  
There is one 10 ton bridge crane in the boiler shop that is used for general movement of materials and parts.
- A-frame cranes
  - There are two 1 ton A-frame cranes in the tap changer area. These A-frame cranes are used in the general movement and lifting of tap changers.
- Forklifts
  - Forklifts are used to move auxiliaries and parts. Currently there are 3 working forklifts from Mitsubishi that all have a maximum carrying weight of 3 tons. Two of the forklifts are shared by various departments and the bushing and CT area have their own forklift. When a 10 ton forklift is needed PDS currently asks PGS if they are allowed to use their 10 ton forklift.
- Trucks
  - Trucks are used to transport the transformers and heavy non-tank parts to and from site.
- Bogies
  - Bogies are used to move fully assembled transformers, tanks and parts between the medium transformer area and the large transformer area. Bogies are used to move windings to and from the windings area, to the medium transformer and large transformer areas. Bogies also transport tanks and parts to and from the paint shop.
- Scotch carts
  - Scotch carts are used to move CTs and bushings to and from the workshop to the bushings area. Scotch carts are used to move smaller winding materials between different areas. Scotch carts are also used to move material to and from the workshop to the boiler shop and/or maintenance.

## 7.5. Material Handling In the Medium Transformer Aisle

### 7.5.1. Un-tanking, disassembly, testing and tanking area

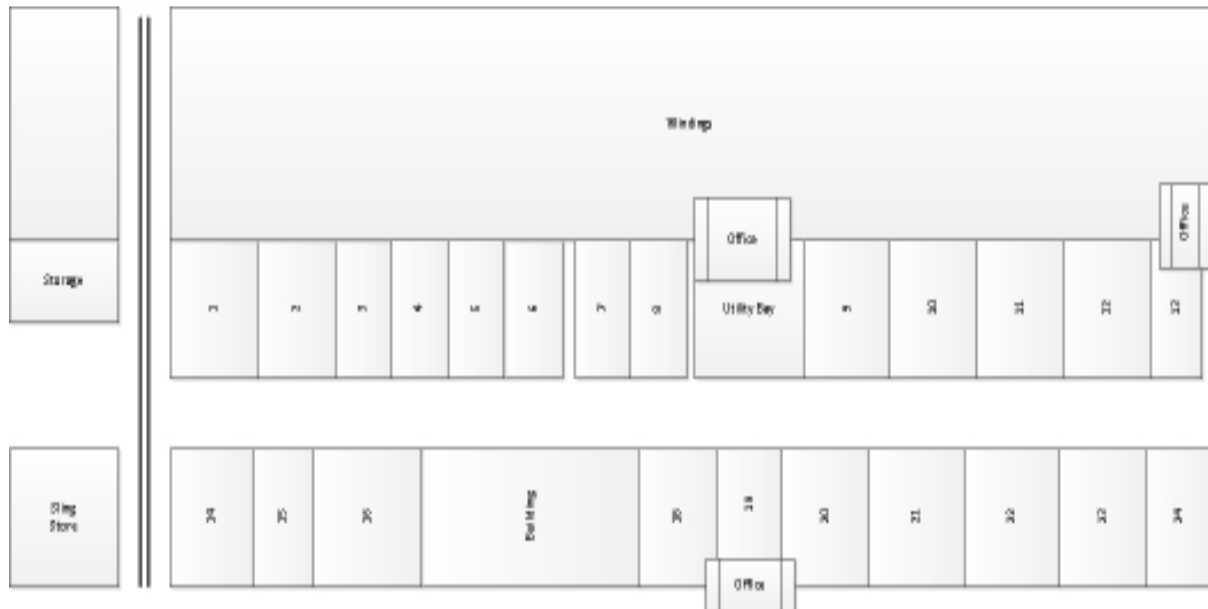


Figure 12: The southern section of the medium transformer aisle

- The off-loading of tanked transformers is done by the bridge crane. A truck enters the building and the crane, with slings, shackles and sometimes the beam, unloads the tanked transformer to the medium transformer workshop floor.
- During un-tanking the bushings, insulators and CTs are removed from the tank with a crane. Preferably with the jib cranes that are provided. The bushings are then placed into boxes and transported to the auxiliary area, specifically to the CTs and bushings area, with a 3 ton forklift. Small bushings, insulators or CTs can be transported with a scotch cart. Bushings and CTs are moved back to the tanking area in the same way.
- During un-tanking the active parts are moved to the disassembly area with the crane and its utilities. The tank cover is removed with the crane. The active part is returned to the tanking area in the same way.
- After un-tanking the cover of the tank is put back on with the crane. It is then bolted, sealed and then transported to the storage area on the plinth with a 10 ton forklift. The tank is returned to the tanking area in the same way. Tanks are also moved to the paint shop with a Bogie on a rail.
- From disassembly the windings are moved to storage or to the winding area by first using the crane and then a Bogie between the windings area and the medium transformer area.
- From disassembly the tap changers are removed with the crane, preferably with the jib crane, and then transported to the auxiliary area, specifically the tap changer area, with a forklift or for smaller tap changers with a scotch cart.
- From disassembly the harness is moved to the storage area with the bridge crane.

### 7.5.2. Final assembly area



Figure 13: The northern section of the medium transformer aisle

- The core, harness is moved to the medium transformer assembly area with the bridge crane.
- The windings are moved from the winding area to the 200 ton assembly area first by the Bogie on a rail and then with the bridge crane to the assembly bay.
- Tap changers are moved to the assembly area with a forklift and is put in place by the jib crane or the bridge crane.
- After assembly the active part is moved to the ovens using the bridge crane.
- The active part is then moved to the tanking area with the bridge crane.

## 7.6. Material Handling In the Large Transformer Aisle

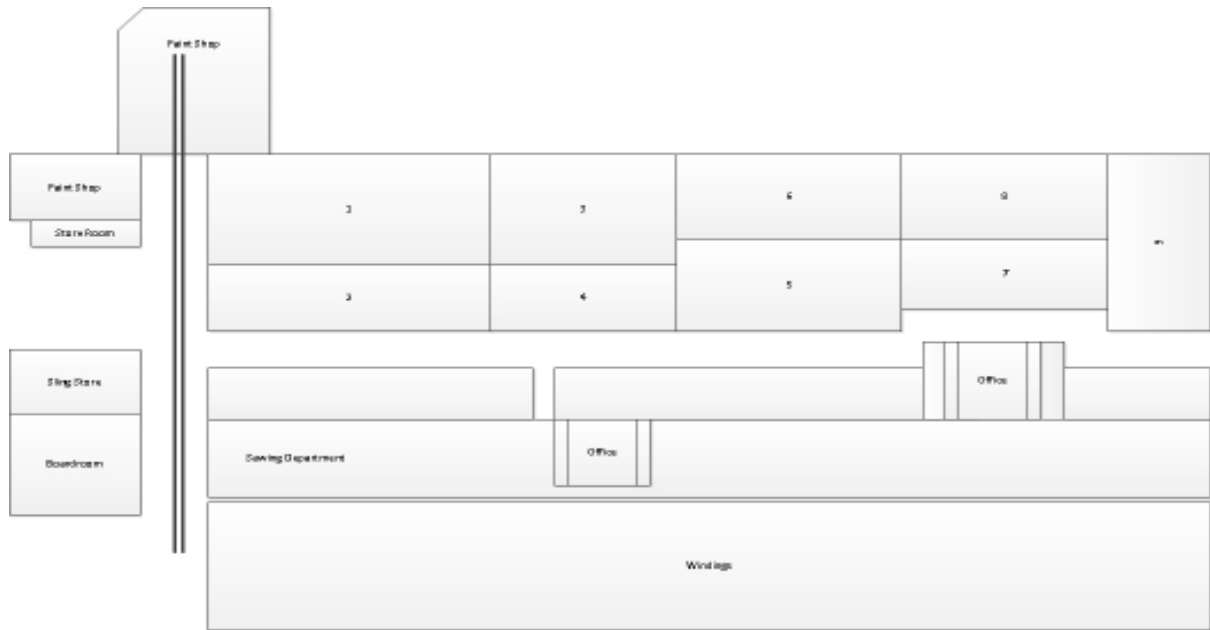


Figure 14: The southern section of the large transformer aisle

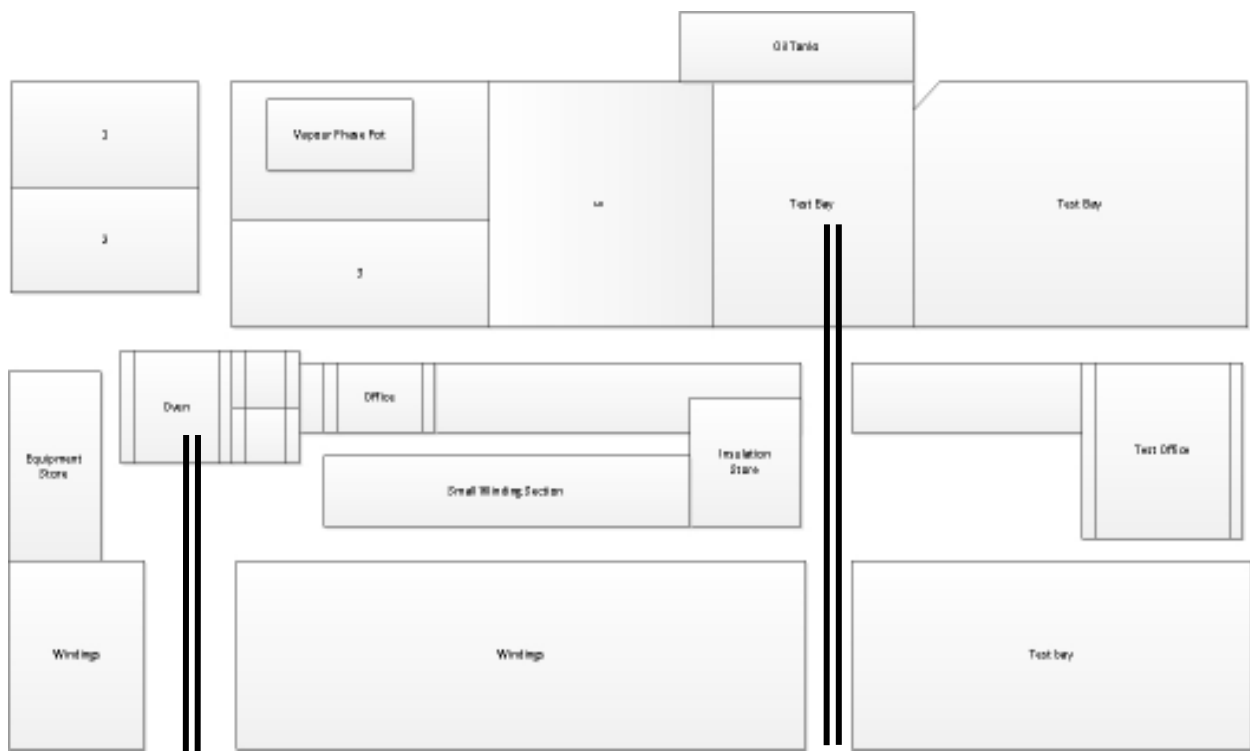


Figure 15: The northern section of the large transformer aisle

- Unloading is done when a truck is reversed into the large transformer area. The bridge crane then transports the fully assembled transformer to the un-tanking area.
- During un-tanking the active part is moved to the disassembly area with the bridge crane. The active part is moved back to the tanking area in the same way.
- During un-tanking the bushings, insulators and CTs are removed by the jib crane or the overhead crane. The bushings are placed in a boxed container and transported to the auxiliary area, specifically the bushing and CT area, with a forklift. Bushing, insulators and CTs are moved back to the tanking area in the same way.
- During un-tanking the tank can be moved to storage with a crane (storage within the workshop), a forklift (storage in tank and parts), or moved to the paint shop with a Bogie on a rail. Mostly the tank is being stored on the workshop floor. The tank is moved back to the tanking area in the same ways.
- During disassembly the tap changers are removed with the crane and transported to the auxiliary area, specifically the tap changer area, with a forklift. Tap changers are moved back to the assembly area in the same way.
- During disassembly windings are removed by the bridge crane and transported to the winding area with a Bogie on a rail. Windings are moved to the assembly area in the same way.
- During disassembly the harness is moved to storage with the bridge crane. The harness moved back to the assembly area in the same way.
- After disassembly the core can be moved to storage with the bridge crane. The core is moved back to the assembly are in the same way.

## **7.7. Material Handling In the Winding Area**

- Smaller windings that come from the medium transformer disassembly area are moved by a scotch cart. Larger windings that come from the medium transformer and the large transformer disassembly areas are moved with a Bogie and with bridge cranes.
- Copper is mostly moved by the crane, but small copper rolls are moved by hand.
- Insulating paper is moved by hand because of its light weight.
- The windings are moved to and from the compression area using the bridge crane.
- The windings are moved to and from the ovens using the Bogies and the bridge cranes

## 7.8. Material Handling In the Auxiliary Area

### 7.8.1. Tap changer area



Figure 16: The tap changer workshop

- The tap changers are moved to and from the workshops in boxed containers with a forklift.
- The tap changers are moved around within the tap changer area with an A-frame crane and a forklift.
- There is an approval set for a bridge crane in the area.

## 7.8.2. Bushing and CT Area

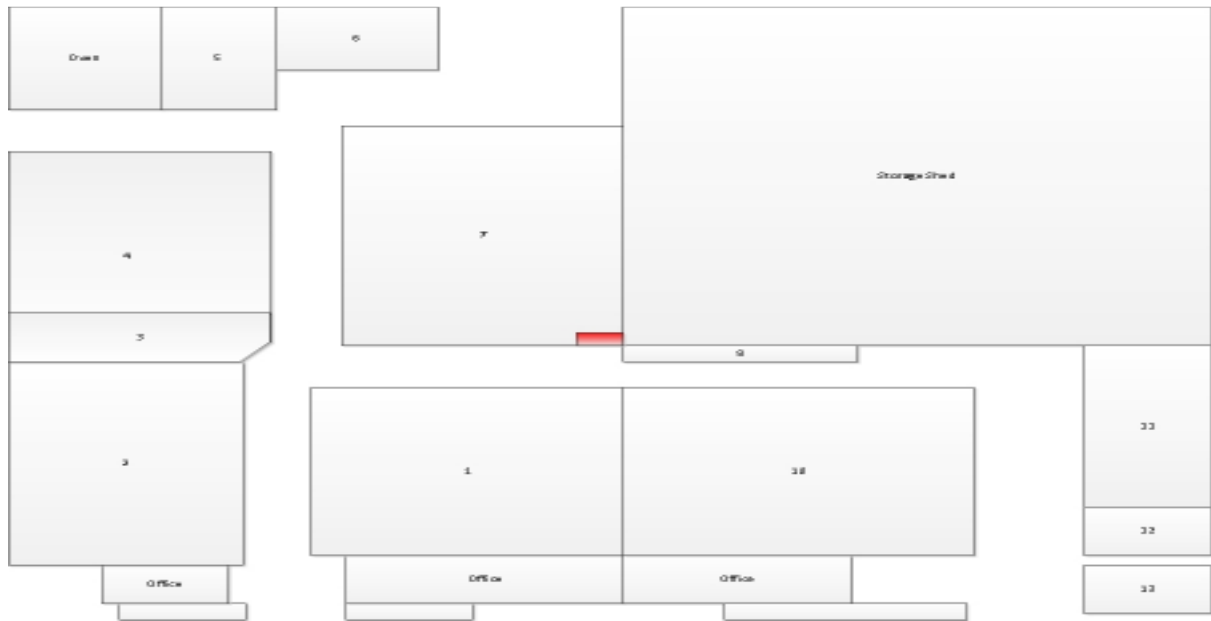


Figure 17: The bushing and CT workshop

- CTs, bushings and insulators are boxed and moved to the CT and bushing area with a forklift or a scotch cart. It is transported back to the workshops in the same way.
- This area has its own forklift.
- CTs, bushings and insulators are mostly moved around within the area with a bridge crane. Smaller materials are moved by hand.
- CTs, bushings and insulators are moved to the oven on a forklift.

### 7.8.3. Boiler shop

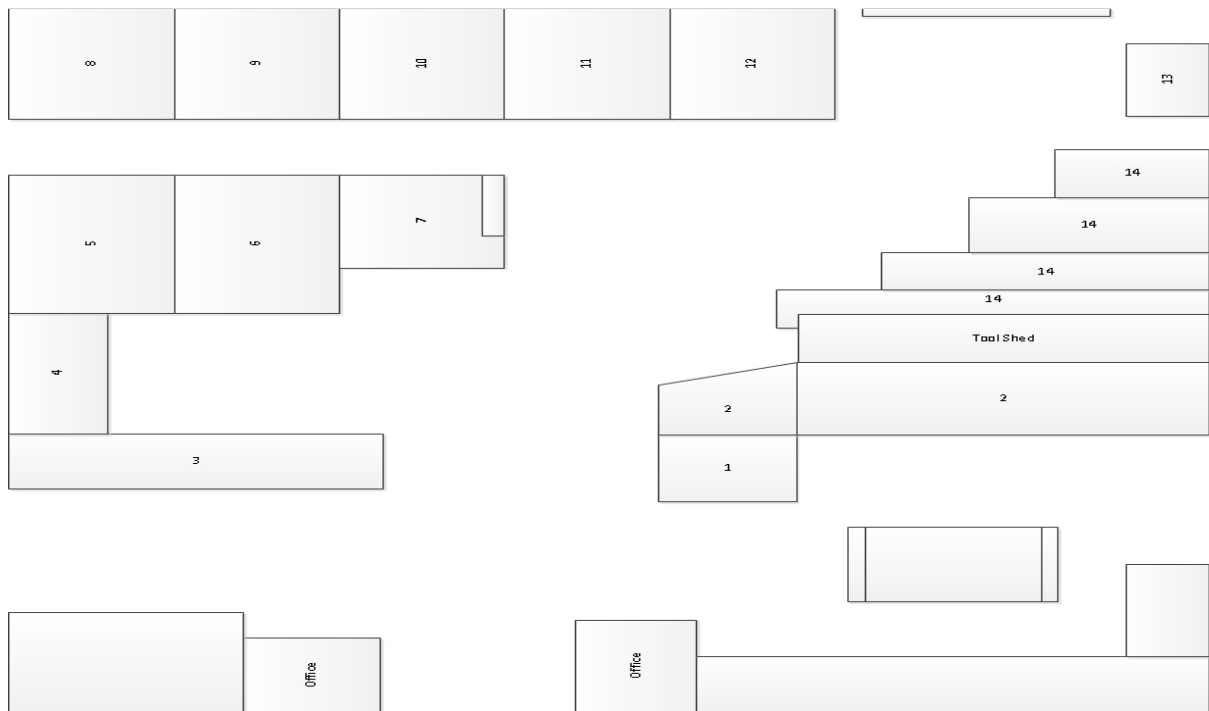


Figure 18: The boiler shop

- Parts and material, like plates, channel lines and flat bars, that come in are transported by a forklift and offloaded by the bridge crane.
- Small material and parts are moved by hand inside the area.
- Big materials and parts are moved around in the area by the bridge crane.

## 7.9. Material Handling In Receiving and Dispatching

- Transformer parts are moved to the tank and parts area with a truck and offloaded with a forklift. A 10ton forklift is also used to transport some parts.
- Copper rolls are moved to and from the winding area with a 3 ton forklift.
- Clacks and other small winding materials are stored inside the winding area. The transport of these small winding materials is done by hand.

## 7.10. Material Handling In Tank and Parts (plinth)

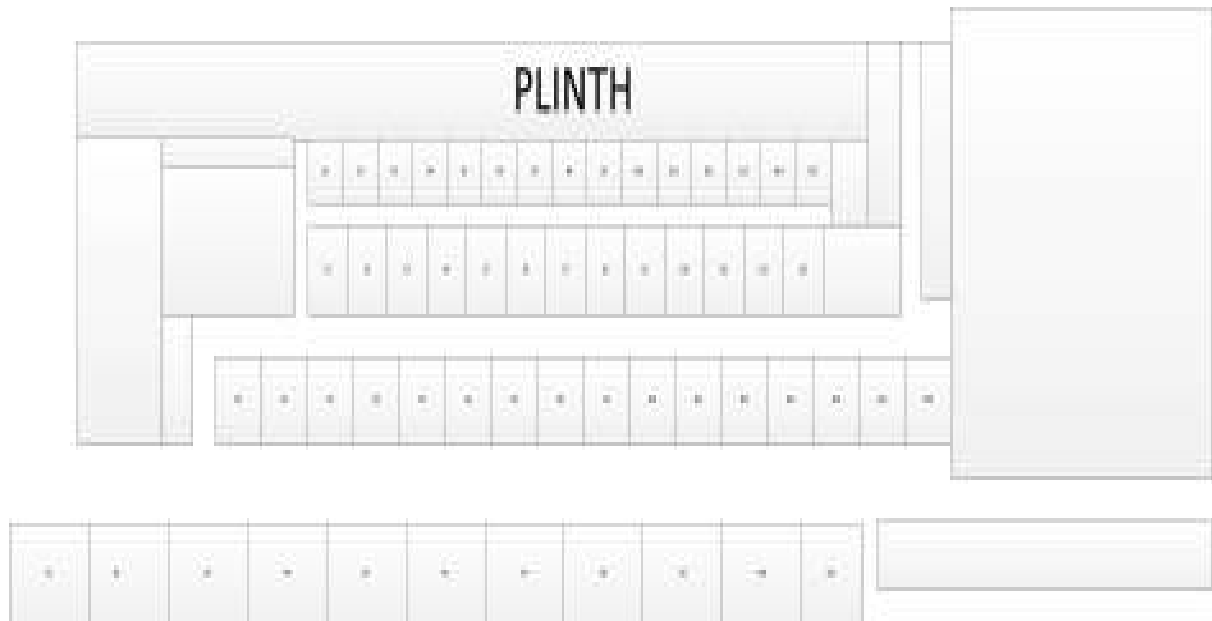


Figure 19: The plinth

- Medium transformer tanks are transported to and from the plinth with a 10 ton forklift.
- The transport of a fully assembled medium transformer or large transformer or tank will require a truck and a mobile yard crane.
- Currently tanks and parts are tracked by steel tags.

## 8. Utilization estimates within the facility

These are rough estimates. The estimates are made to accommodate the busiest current times in PDS. Therefore most estimates are probably over-estimated. With more time proper utilization readings could be taken.

### 8.1. Current utilization

#### 8.1.1. Jib cranes

- Jib cranes have utilization of less than 10% in the 600 ton workshop. The utilization of the jib cranes need to improve drastically.
- Jib cranes have utilization of less than 15% in the 200 ton workshop. The utilization of the jib cranes need to improve drastically.

#### 8.1.2. Bridge Cranes

- The large bridge cranes in the 600 ton workshop have utilization of less than 35%. If the utilization of jib cranes improves to 15 to 20% the utilization of bridge cranes could reduce to less than 30%. When the space issue is resolved this utilization should decrease even more.
- The bridge cranes in the 200 ton workshop have utilization of less than 45%. If the utilization of jib cranes improves to 20 or 30% the utilization of bridge cranes can be reduced to less than 30%.
- The bridge cranes in the winding workshop have utilization of less than 40%.
- The bridge crane in the bushing and CT area has utilization of less than 30%.
- The bridge crane in the boiler shop has utilization of less than 30%.

#### 8.1.3. A-frame cranes

- A frame cranes are utilized less than 35% of the time.

#### **8.1.4. Forklifts**

- The two 3 ton forklifts that are currently used by various departments are utilized up to 70% of the time. When there is a build-up of work these two forklifts can't handle the load.
- The 3 ton forklift that is used by the bushing and CT workshop is utilized less than 40% of the time. This forklift should be shared with the other auxiliary workshops to lighten the loads of the other two forklifts.
- If any increase in throughput is required an extra 3 ton forklift would be needed. Repaired, rented or bought.

#### **8.1.5. Trucks**

- Trucks are mainly used to transport transformers and non-tank parts to and from site. There will be no focus on the trucks in this project. Except to improve movement of tanks or parts to and from the plinth (Tank & Parts)

#### **8.1.6. Bogies**

- The Bogie that moves between the 200ton workshop and the winding workshop is utilized less than 25% of the time.
- The Bogie that moves between the 200ton workshop and the winding workshop is utilized less than 30% of the time.
- The Bogie that moves from the 200ton workshop to/through the 600ton workshop to the paint bay is utilized up to 65% of the time. However the Bogie is sometimes not moving but a transformer tank is stored on the Bogie to wait in queue for the paint bay. If this is taken into consideration the actual utilization of transport/movement is less than 40%.

#### **8.1.7. Scotch carts**

- Scotch carts are utilized less than 30% of the time. Scotch carts are slow and take a long time to transport parts/material and consideration should be taken to batch parts or material and transport it via forklift. This will increase the utilization of the forklift.

## 9. Alternative Facility Layouts

These alternative layouts were designed in a previous student vacation project for Rotek Engineering PDS. However they were not finalized. Power Distribution Services wishes to finalize these alternatives by determining the correct amount of working bays for every activity. The following sections show the changes in the facility and general comments about the alternative.

### 9.1. Alternative 1

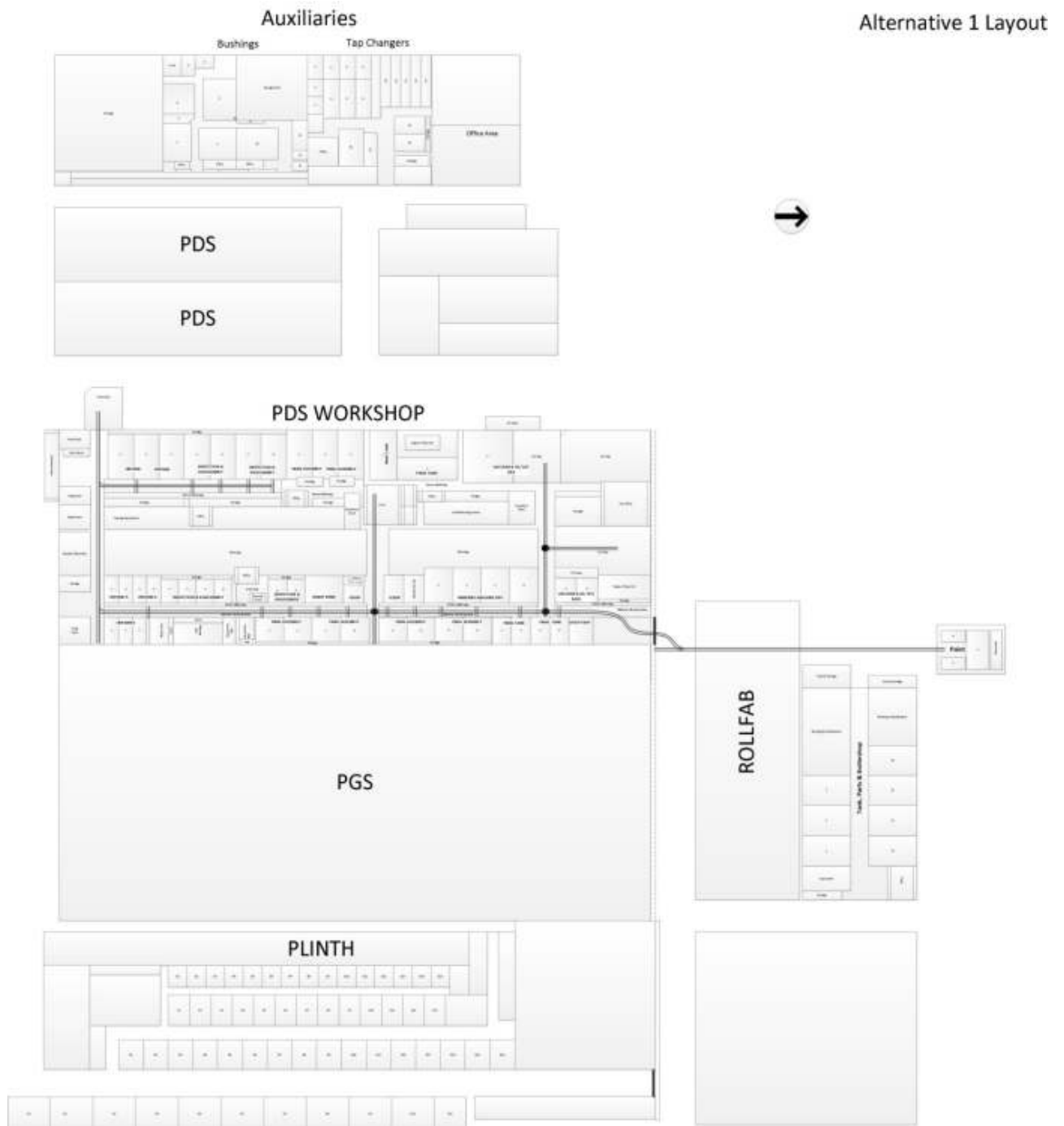


Figure 20: The 1st facility layout alternative

### 9.1.1. The Medium Transformer Aisle

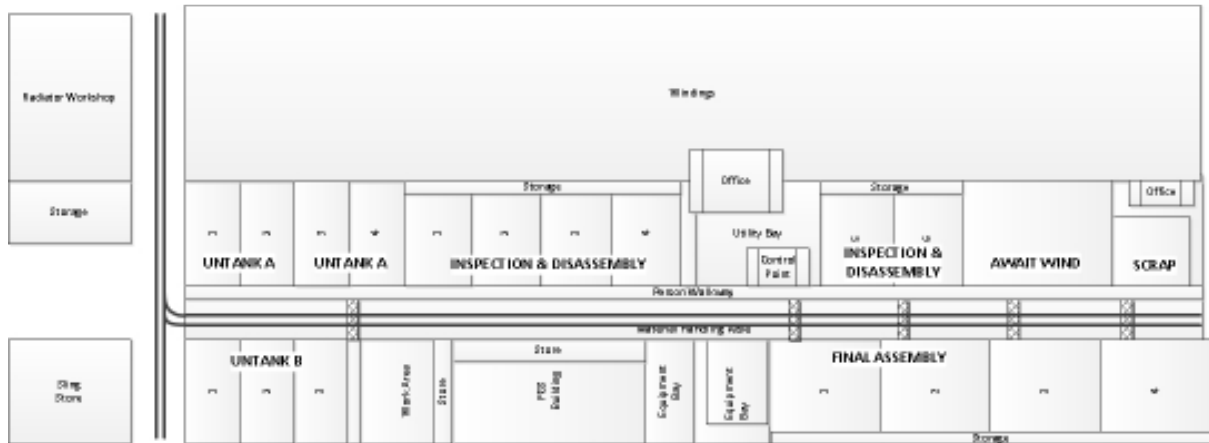


Figure 21: Alternative 1 medium transformer aisle (South)

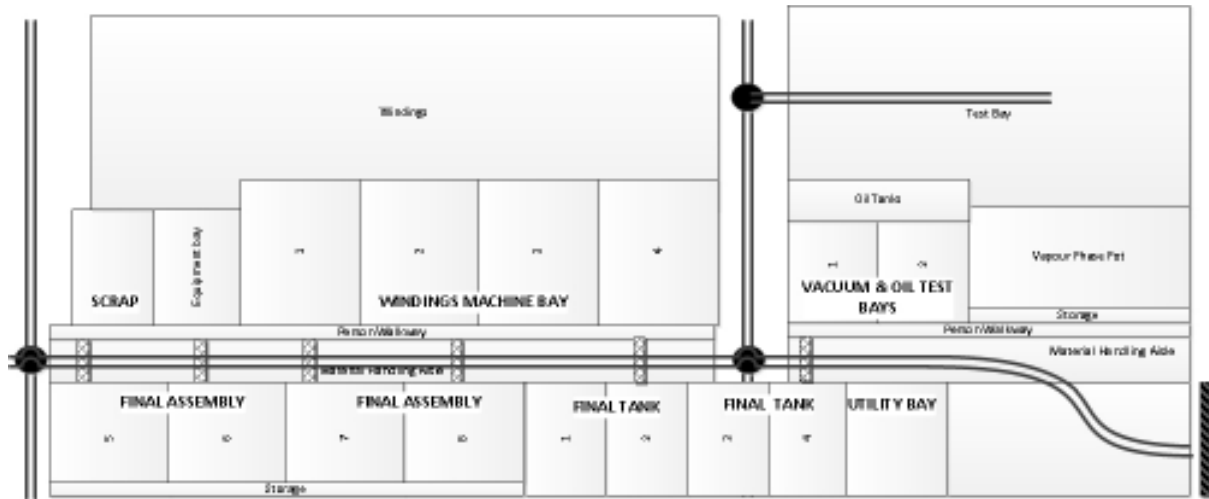


Figure 22: Alternative 1 medium transformer aisle (North)

Changes in layout design Alternative 1 from the current layout include:

- The inclusion of a material handling aisle and person walkway throughout the entire length of the medium transformer aisle.
- The rearranging of bays to allow for the sequential flow of materials
- Removal of the storage of tanks.
- A rail Bogie system that runs the entire length of the medium transformer aisle.
- The inclusion of person crossings to reach the opposing sides in the workshop.
- The relocation of vacuum & oil testing, final assembly and the winding machine bay.

The final assembly area will be surrounded by clean condition walls with gates for each of the proposed bays to allow for easy access. The wall between the original windings area and the proposed move of the winding machine bay area should be demolished to allow for one common winding area. The door and security gate on the northern side of the workshop should be replaced to allow the easy exit of transformer tanks as they make their way to the proposed new facilities. It is suggested that the minimum width of the door and gate be 10 m.

### 9.1.2. Large Transformer Aisle

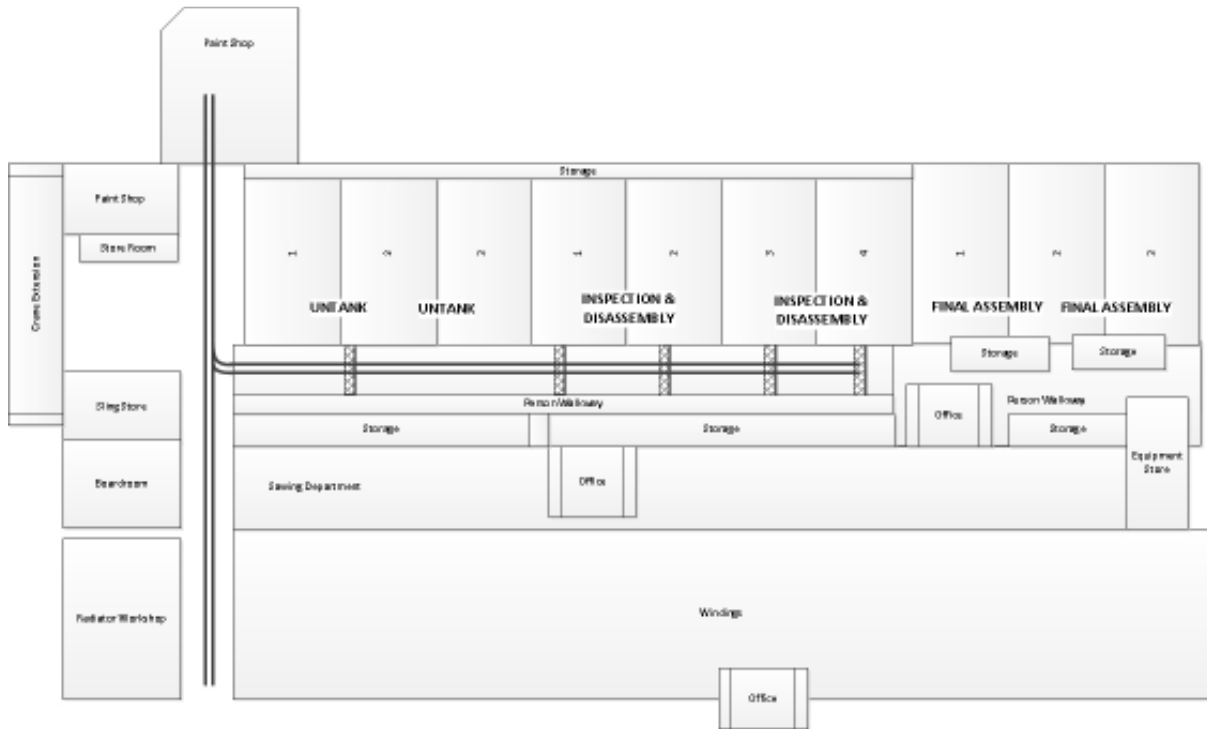


Figure 23: Alternative 1 large transformer aisle (South)

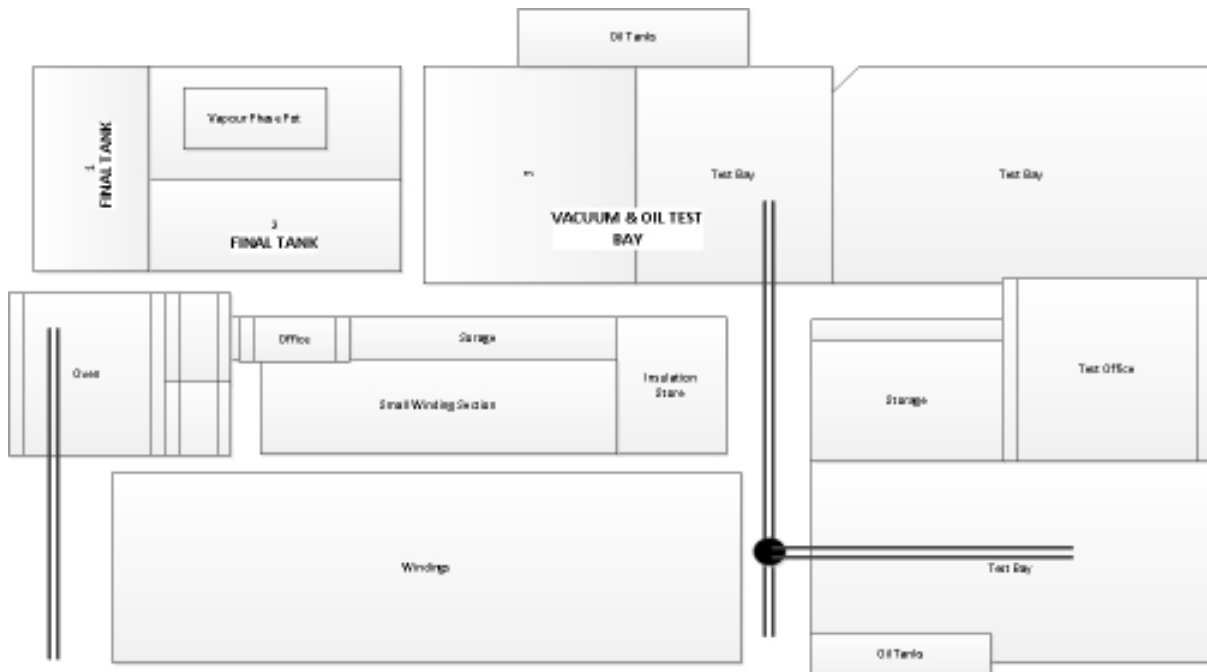


Figure 24: Alternative 1 large transformer aisle (North)

Changes in layout design 1 from the current layout include:

- The inclusion of a material handling aisle and person walkway
- The rearranging of bays to allow for the sequential flow of materials
- The removal of the storage of tanks
- A rail Bogie system that runs the partial length of the large transformer aisle.
- The inclusion of person crossings to reach the opposing sides in the workshop.
- The inclusion of a bridge crane extension to allow easier access during shipping and receiving.

The northern region of the large transformer aisle contains several fixed points thus preventing the rearrangement of certain processes.

### 9.1.3. Auxiliaries

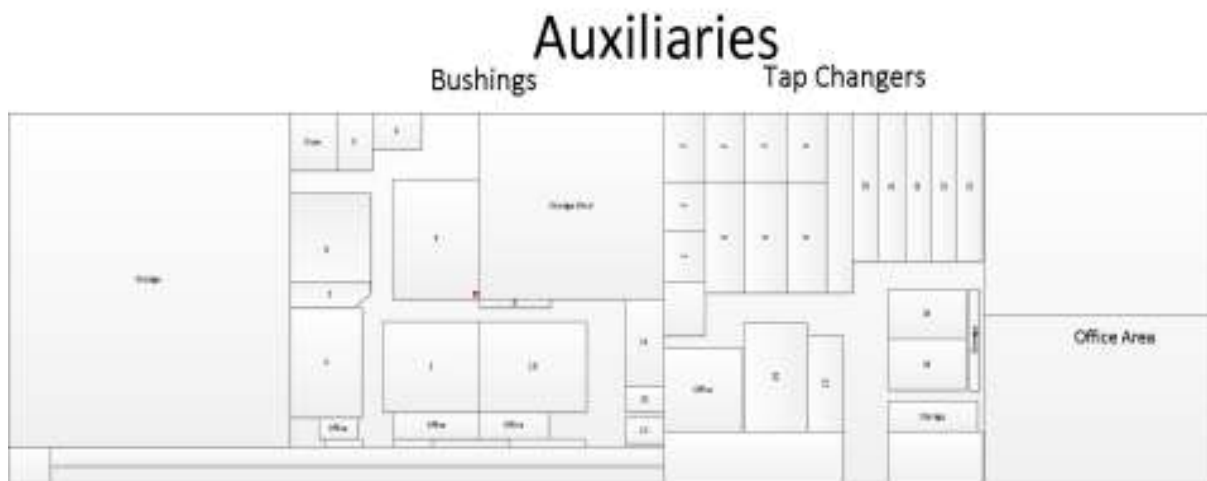


Figure 25: Alternative 1 Auxiliaries

Changes in layout design 1 from the current layout include:

- Moving the boiler shop from its current location to the proposed safeguard tank & parts facility.
- Moving the tap changer shop to the area where the boiler shop is currently situated.
- Implementing a storage area in the current tap changer shop to allow for an increase in capacity.

Dimensions of the proposed bays for the new layout are recommended to remain the same as the current specifications.

#### 9.1.4. Proposed New Facilities for Alternative 1



Figure 26: Alternative 1 new facilities

Changes in layout design 1 from the current layout include:

- Moving the boiler shop and tank & parts repair from their current locations to the proposed safeguard tank & parts facility.
- The boiler shop will include an outside storage area.
- Demarcated areas will be present to allow for the fabrication of tanks.
- Utilising the extra paint shop which will include three bays and a storeroom.
- A rail Bogie system will extend from the medium transformer aisle door to the proposed new paint shop

Currently Power Generation Services (PGS) partially use the rail Bogie system, therefore only a part of the system needs to be upgraded.

## 9.2.Alternative 2

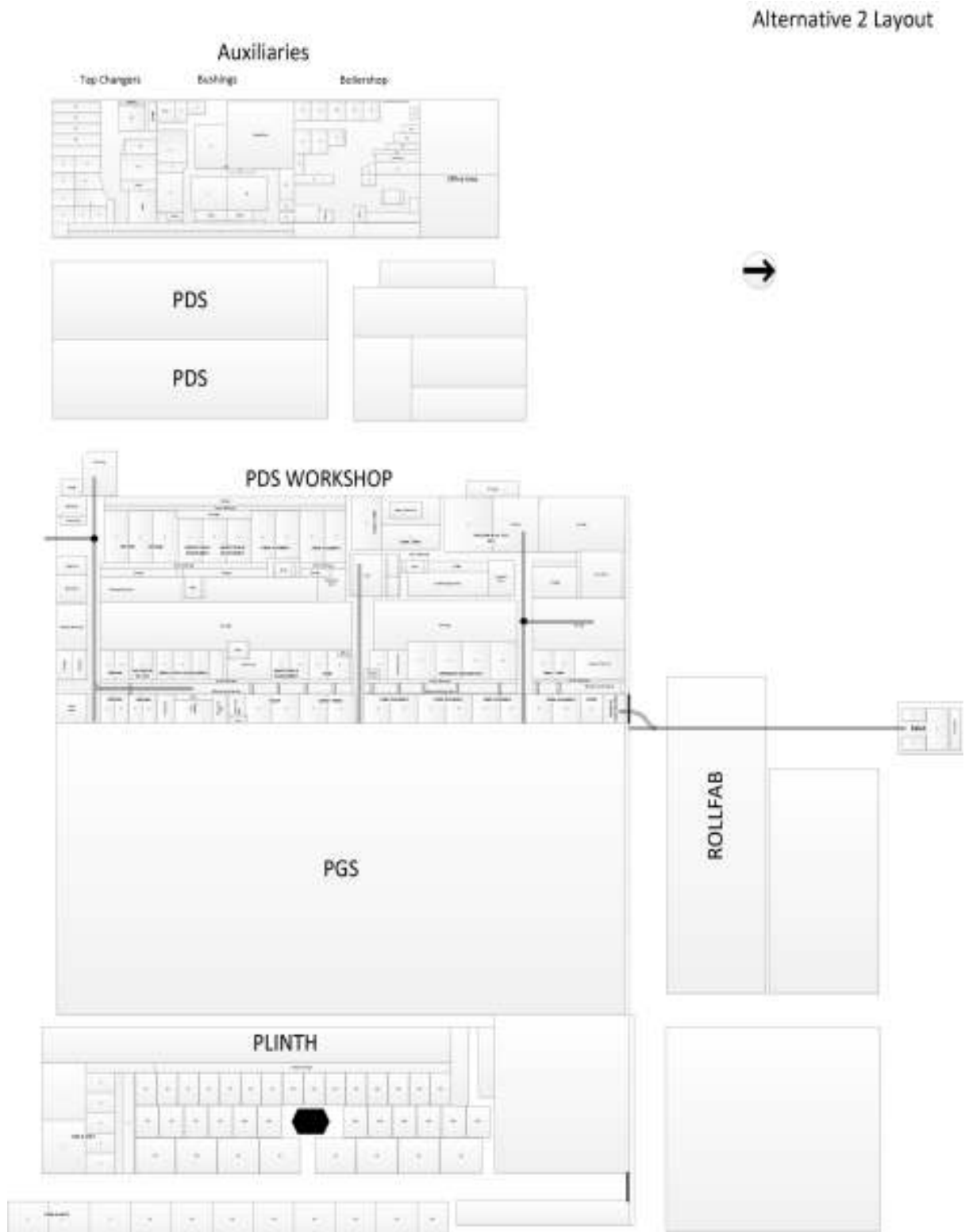


Figure 27: The 2nd facility layout alternative

### 9.2.1. The Medium Transformer Aisle

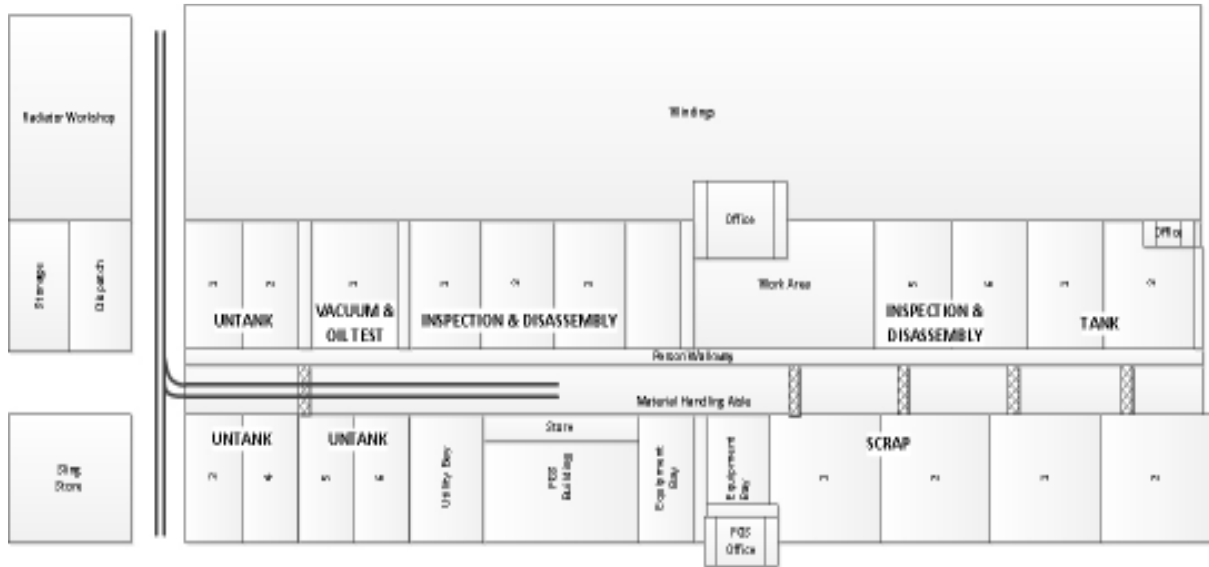


Figure 28: Alternative 2 medium transformer aisle (South)

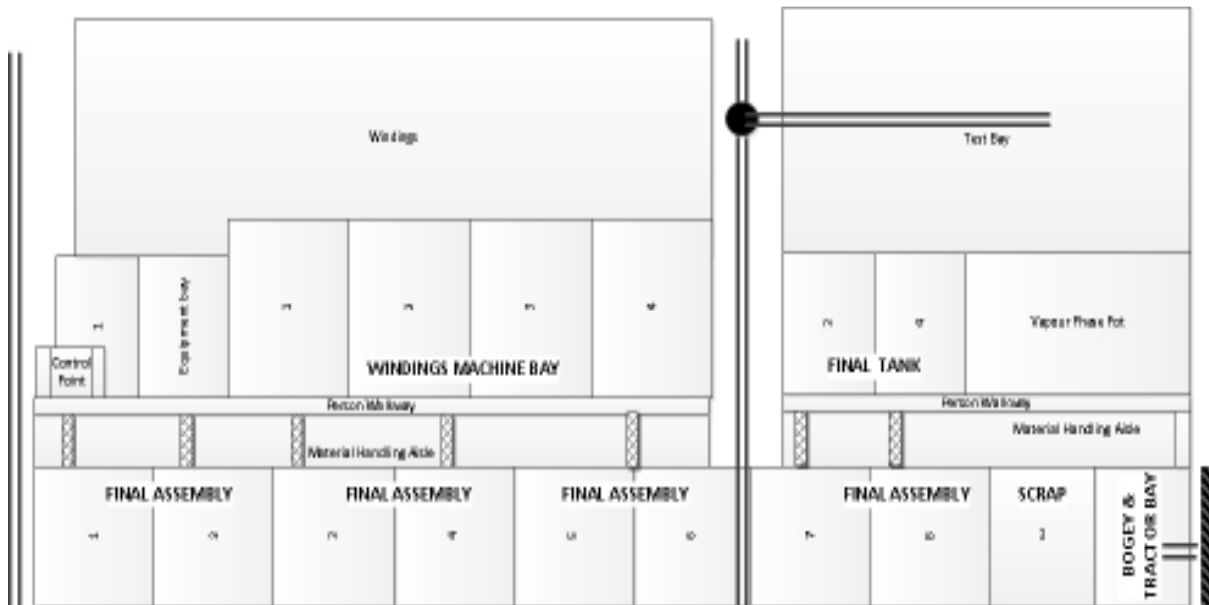


Figure 29: Alternative 2 medium transformer aisle (North)

Changes in layout design 2 from the current layout include:

- The inclusion of a material handling aisle and person walkway throughout the entire length of the medium transformer aisle.
- The rearranging of bays to allow for the sequential flow of materials
- The removal of the storage of tanks
- A rail Bogie system that runs the partial length of the medium transformer aisle.
- The inclusion of person crossings to reach the opposing sides in the workshop.
- The relocation of final assembly and the winding machine bay.

The final assembly area will be surrounded by clean condition walls with gates for each of the proposed bays to allow for easy access. The wall between the original windings area and the proposed move of the winding machine bay area should be demolished to allow for one common winding area. Forklifts will run the entire length of the material handling aisle while a Bogie system using the forklifts will be used to exit the aisle through the proposed door on the northern side of the workshop.

## 9.2.2. The Large Transformer Aisle

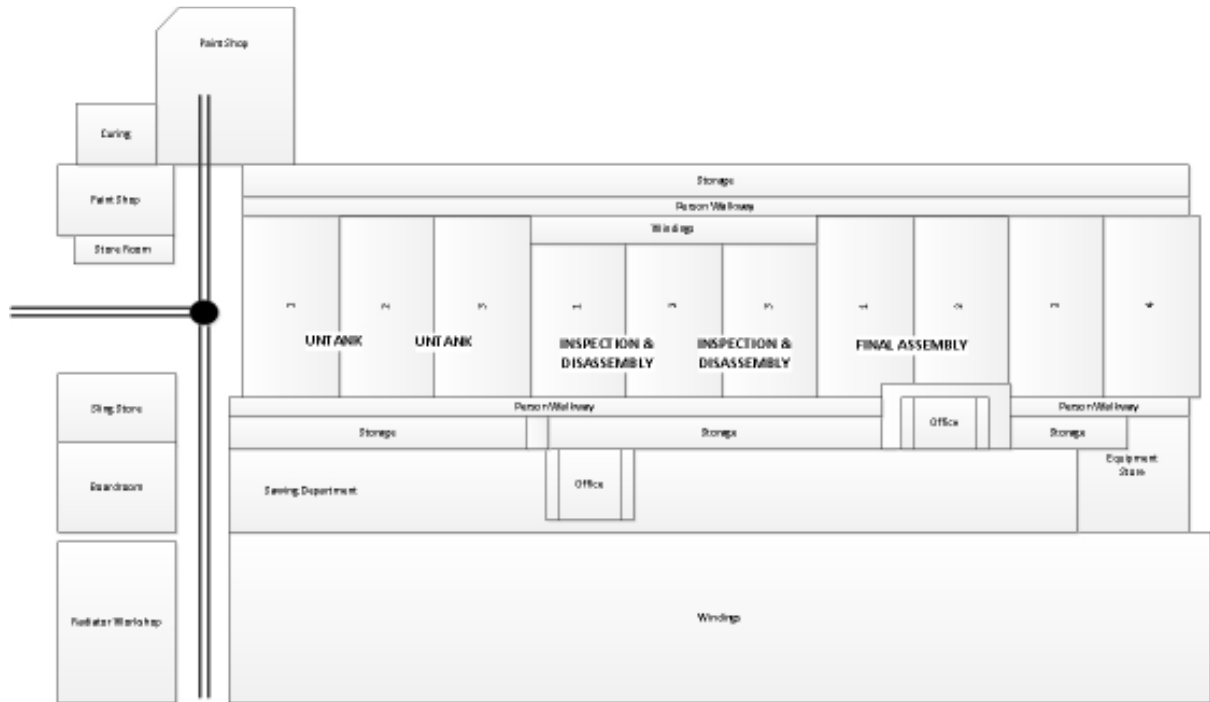


Figure 30: Alternative 2 large transformer aisle (South)

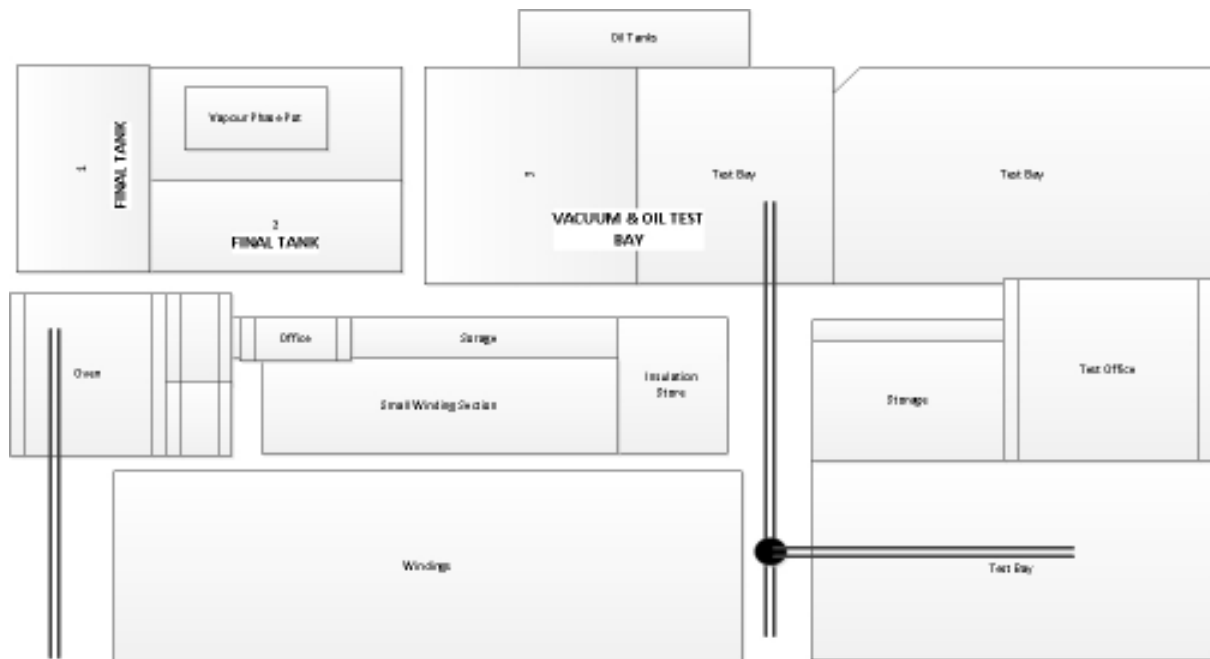


Figure 31: Alternative 2 large transformer aisle (North)

Changes in layout design 2 from the current layout include:

- The inclusion of a material handling aisle and person walkway.
- The rearranging of bays to allow for the sequential flow of materials
- The removal of the storage of tanks
- A rail Bogie system that runs the partial length of the large transformer aisle.
- The inclusion of person crossings to reach the opposing sides in the workshop.
- The extension of the rail Bogie system outside the main entrance of the large transformer aisle to allow for easier access during shipping and receiving.

The northern region of the large transformer aisle contains several fixed points thus preventing the rearrangement of certain processes. This layout contains dual person walkways to facilitate movement throughout the workshop. Designated storage areas for windings have been provisioned and a curing oven has been included in this layout

### 9.2.3. Tank and Parts (Plinth)

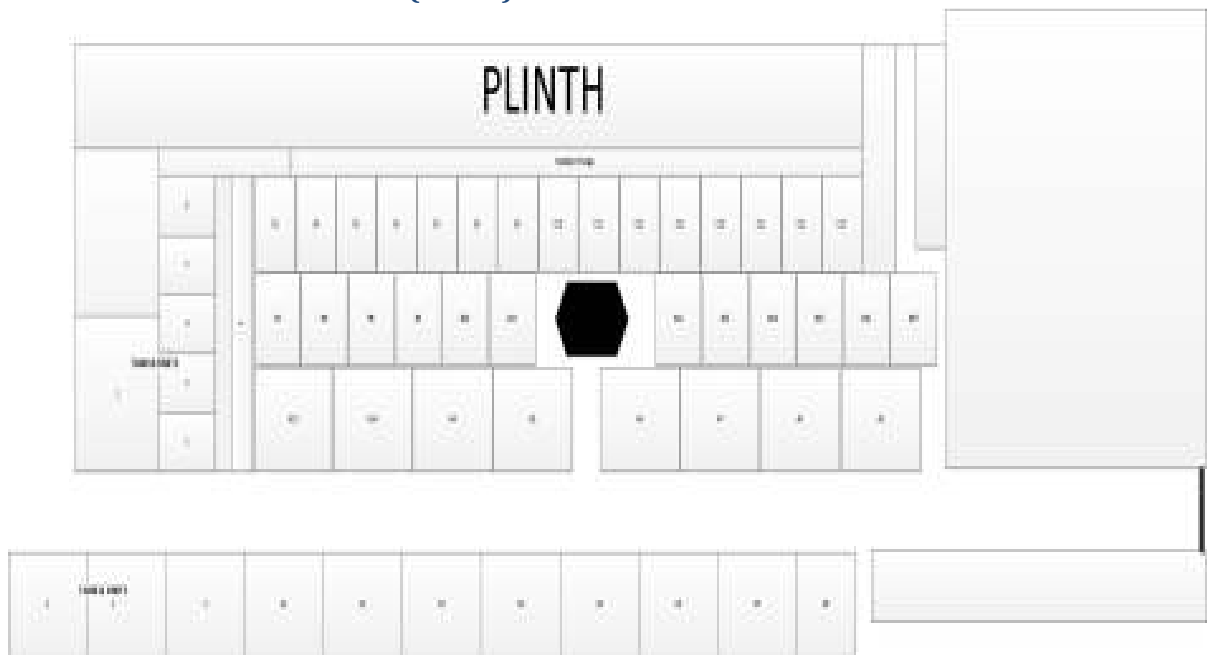


Figure 32: Alternative 2 Plinth

Changes in layout design 2 from the current layout include:

- The implementation of a tower crane to handle materials for the various bays.
- The rearrangement of bays (elimination of handling aisles) to allow for increased storage.
- The allocation of a tank & parts area to alter various parts related to the transformer.
- The implementation of a new road and gate to facilitate the movement of materials to the safeguard paint facility.
- The implementation of forklifts to handle materials.

#### 9.2.4. Proposed New Facilities for Alternative 2

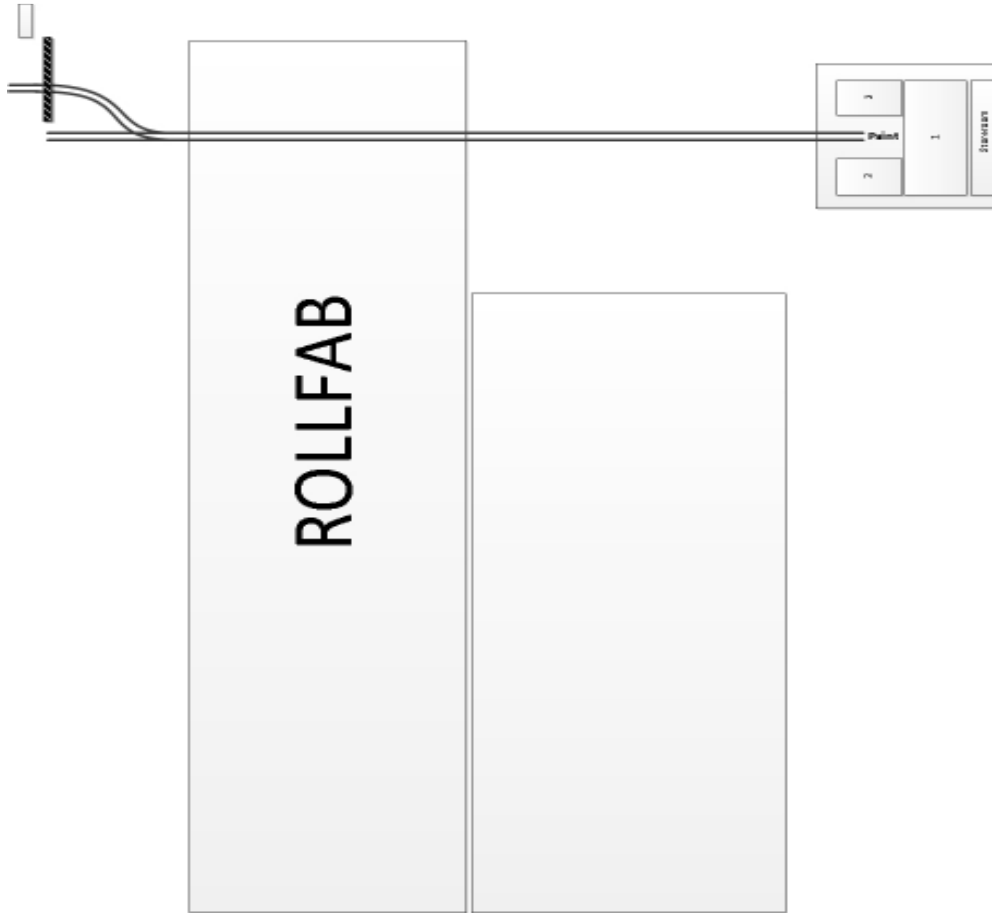


Figure 33: Proposed new facilities for alternative 2

Changes in layout design 2 from the current layout include:

- Utilising the extra paint shop which will include three bays and a storeroom.
- A rail Bogie system will extend from the medium transformer aisle door to the proposed new paint shop.

Currently Power Generation Services (PGS) partially use the rail Bogie system, therefore only a part of the system needs to be upgraded

## 10. Basic Activities for Transformers and the Order

### 1. Un-tanking

This is the process of removing the active part from the tank. The active part of the transformer is then moved to the dismantling and repair area. The tank and external part is moved towards tank and parts for external repairs. The bushings are transported to the bushing workshop.

### 2. Dismantling and Repair

The transformer active part is then dismantled and repaired. The tap changer is transported to the tap changer workshop in the auxiliary area. Windings are moved to the winding workshop to be repaired, maintained or rewound.

### 3. Winding Assembly

After repairs the active part is reassembled, this task is done within a clean area and should be done carefully. The windings are returned and assemble on to the active part.

### 4. Active Parts Assembly

This process is also within the clean area and is also a slow and careful process. This sees the return of tap-changers from the tap changer workshop.

### 5. Pre and final Drying

After the assembly of the active part the drying process starts. It is essential that the active part is extremely dry.

### 6. Tanking

After the drying process the active part is re-inserted into the tank. This process should be done as quickly as possible to avoid the accumulation of moisture.

During this process the bushings are returned and added to the tank.

- Note: During all these processes the tank is repaired and sent to the paint bay, and all the auxiliary parts are sent to their respective areas, repaired and returned.

## 10.2. Activity Bays in the Medium Transformer Aisle

### • Un-tanking Bays

The un-tanking bays are used to take the active parts out of the tank for processing. The tank is then sent to the plinth area for tank repairs or for tank storage. Auxiliary parts are sent to their respective workshops for repairs.

### • Dismantling and Repair Bays

The dismantling and repair bays are used to disassemble active parts and to do any repairs to the active parts that are needed. Any auxiliary parts are sent to their respective workshops for repairs.

- **Active Part Storage Bays**

The active part storage bays are used as buffers or waiting areas. The active parts are stored until a spot is opened in the assembly bay areas.

- **Assembly Bays**

Assembly bays are in clean condition areas. These areas are kept as dust free as possible to ensure the correct and safe assembly of active parts. Some auxiliary parts are returned to the active parts.

- **Vapour Phase Bays**

The vapour phase is used to take any moisture out of the active parts. This is essential because the moisture and the oil within a transformer do not mix and this causes problems and the transformer might not be able to work sufficiently.

- **Tanking Bays**

Active parts are inserted back into the tanks in the tanking bays. The final auxiliary parts are also returned to finalize the tanks.

<b>ACTIVITY BAYS</b>	<b>AVERAGE DURATION (DAYS)</b>
Un-tanking	4
Disassembly and Repairs	35
Active Part Storage	As needed
Assembly	14
Vapour Phase	7
Tanking	2
Testing	5
<b>Total</b>	<b>67</b>

**Table 2: Activity duration for medium transformers**

### 10.3. Activity Bays in the Large Transformer Aisle

- **Un-tanking Bays**

The un-tanking bays are used to remove the active parts from the tank. The tank is sent to repair or to the plinth for storage. The auxiliary parts are sent to their respective areas for repairs.

- **Active Part Bays**

These bays are in a clean condition area to keep the transformer clean and safe to ensure the transformer will function correctly when assembled. The active part bays are used to dismantle, repair and reassemble the active parts. Auxiliary parts are moved to their respective areas for repairs.

- **Vapour Phase Bays**

The vapour phase is used to take any moisture out of the active parts. This is essential because the moisture and the oil within a transformer do not mix and this causes problems and the transformer might not be able to work sufficiently.

- **Tanking Bays**

Active parts are inserted back into the tanks in the tanking bays. The final auxiliary parts are also returned to finalize the tanks.

- **Test Bays**

Test bays are used to test finalized tanks to ensure that they are in working order and will be able to function correctly. This area is used for large and medium transformers.

ACTIVITY BAYS	AVERAGE DURATION (DAYS)
Un-tanking	3
Active Part	90
Vapour Phase	7
Tanking	3
Testing	7
<b>Total</b>	<b>110</b>

Table 3: Activity duration for large transformers

## 10.4. Other Activities

These activities work simultaneously with the work done within the medium and large transformer aisles:

- **Bushings Repairs and Storage**  
The bushings are sent to the bushing workshop for repairs and returned to the tanking bays. This area includes the bushings of medium and large transformers.
- **Tap Changer Repairs and Storage**  
The tap changers are sent to the tap changer workshop for repairs and returned to the active part assembly areas. This area also includes the tap changers from the medium and large transformer aisles.
- **Tank and Part Repairs and Storage**  
Tanks need to be repaired before they are painted and sent to tanking. The tanks are from medium and large transformers.
- **Paint**  
The paint bay is used to paint medium and large transformers, one at a time. After painting the tanks are sent to tanking.

ACTIVITIES	AVERAGE DURATION (DAYS)
Bushing Repairs	7
Bushing Storage	As needed
Tap Changer Repairs	10
Tap Changer Storage	As needed
Tank and Part Repairs	5
Tank and Part Storage	As needed
Paint Bay	3

Table 4: Activity duration for other activities

## 11. Amount of Bays Needed

To determine the amount of bays needed for every activity is a two step process. Currently there is a throughput of 54 transformers per year of which 42 are medium transformers and 12 are large transformers. For a throughput of 88 transformers per year there are 68 medium transformers and 20 large transformers. For a throughput of 130 transformers per year there are 100 medium transformers and 30 are large transformers. It is assumed that the company has 240 workdays per year.

**Step 1:** This step is done once for the activity that takes the longest.

$$K = AH/W$$

*K = The Number of Workbays Needed*

*A = Amount of Parts or Units*

*H = Days Needed for the Activity that takes the Longest*

*W = The Number of Workdays in a Year*

**Step 2:** This step is done for every activity listed.

$$k = Bd/H$$

*k = The Number of Workbays Needed*

*B = Activity that needs the highest number of bays (Determined in step 1)*

*H = Days Needed for the Activity that takes the Longest*

*d = Average Duration of the Activity*

### 11.1. Medium Transformers

The table shows the minimum required bays that would theoretically be needed to have the desired throughput in the medium transformer aisle. These are the bays where activities take place, it does not include any storage.

ACTIVITY BAYS	42 TRANSFORMERS; BAYS NEEDED	68 TRANSFORMERS; BAYS NEEDED	100 TRANSFORMERS; BAYS NEEDED
Un-tanking	1	2	2
Dismantling and Repair	7	10	15
Assembly	3	4	6
Vapour Phase	2	2	3
Tanking	1	1	1
Test	1	2	3

Table 5: Number of bays needed per activity for medium transformers

### 11.2. Large Transformers

The table shows the minimum required bays that would theoretically be needed to have the desired throughput in the large transformer aisle. These are the bays where activities take place it does not include any storage.

ACTIVITY BAYS	12 TRANSFORMERS; BAYS NEEDED	20 TRANSFORMERS; BAYS NEEDED	30 TRANSFORMERS; BAYS NEEDED
Un-tanking	1	1	1
Active Parts	5	8	12
Vapour Phase	1	1	1
Tanking	1	1	1
Test	1	1	1

Table 6: Number of bays needed per activity for large transformers

### 11.3. Bushings

The following table shows the theoretically minimum amount of work-bays needed in the bushings workshop. This does not include storage bays. There is an average of 8 bushings per transformer. Therefore there are 432 bushings for 54 transformers, 704 bushings for 88 transformers, and 1040 bushings for 130 transformers respectively.

ACTIVITY BAYS	54 TRANSFORMERS; BAYS NEEDED	88 TRANSFORMERS; BAYS NEEDED	130 TRANSFORMERS; BAYS NEEDED
Bushing Repairs	13	21	31

Table 7: Number of bays needed for bushing repairs

## 11.4. Tap Changers

The following table shows the theoretically minimum amount of work-bays needed in the tap changer workshop. This does not include storage bays. There is an average of 3 tap changers per transformer. Therefore there are 162 bushings for 54 transformers, 264 bushings for 88 transformers, and 390 bushings for 130 transformers respectively.

ACTIVITY BAYS	54 TRANSFORMERS; BAYS NEEDED	88 TRANSFORMERS; BAYS NEEDED	130 TRANSFORMERS; BAYS NEEDED
Tap Changer Repairs	7	11	17

Table 8: Bays needed for tap changer repairs

## 11.5. Tank & Parts

The following table shows the theoretically minimum amount of work-bays needed for tank and parts repairs. This does not include storage bays.

ACTIVITY BAYS	54 TRANSFORMERS; BAYS NEEDED	88 TRANSFORMERS; BAYS NEEDED	130 TRANSFORMERS; BAYS NEEDED
Tank & Parts Repairs	2	2	3

Table 9: Bays needed for tank & parts repairs

## 11.6. Paint

The following table shows theoretically the minimum amount of paint bays that would be needed to have the desired throughput.

ACTIVITY BAYS	54 TRANSFORMERS; BAYS NEEDED	88 TRANSFORMERS; BAYS NEEDED	130 TRANSFORMERS; BAYS NEEDED
Paint	1	2	2

Table 10: Bays needed for tank painting

## 12. Material Flow

### 12.1. Current Material Flow

Current Layout

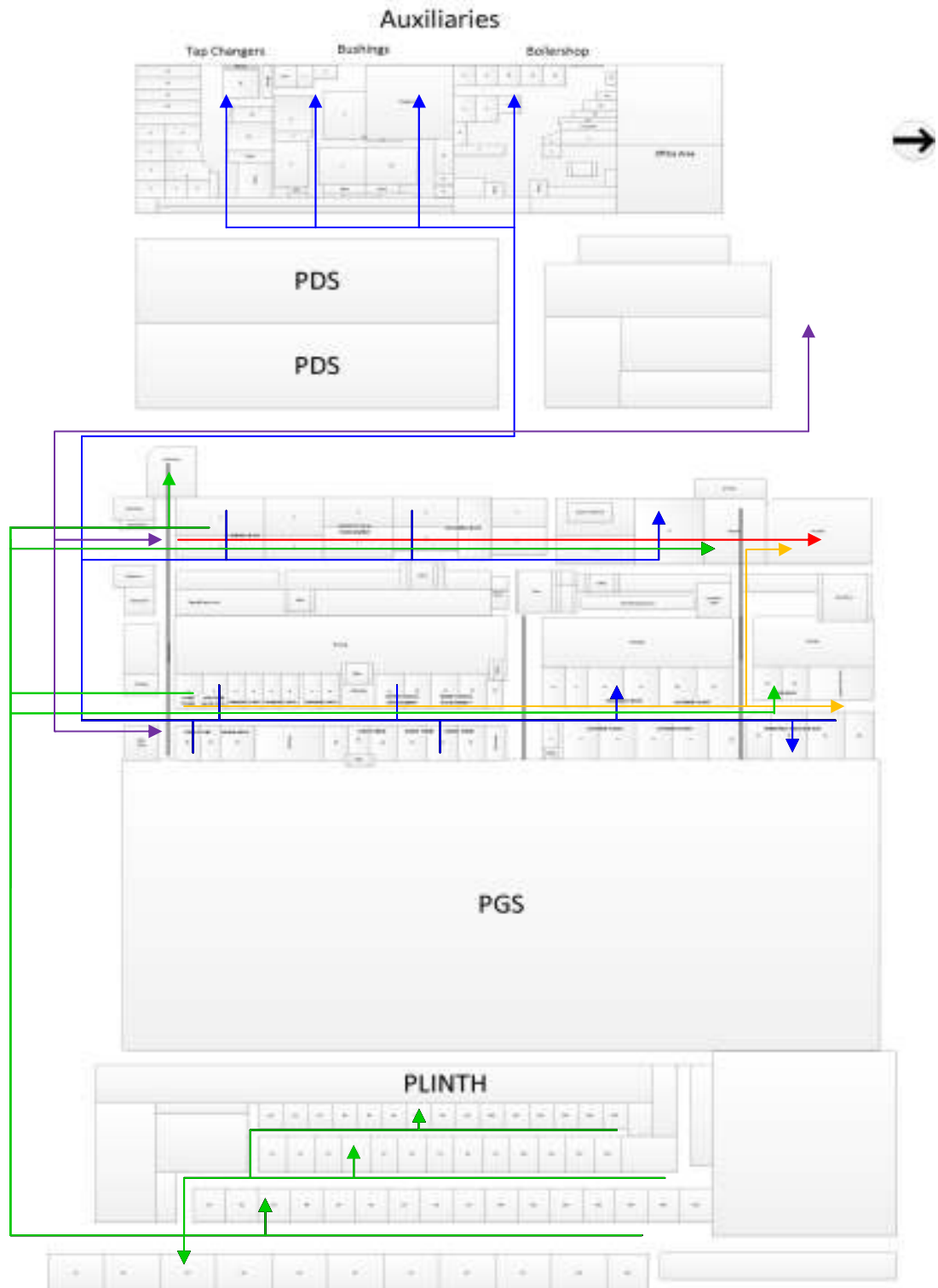


Figure 34: Current material flow

## 12.2. Alternative 1

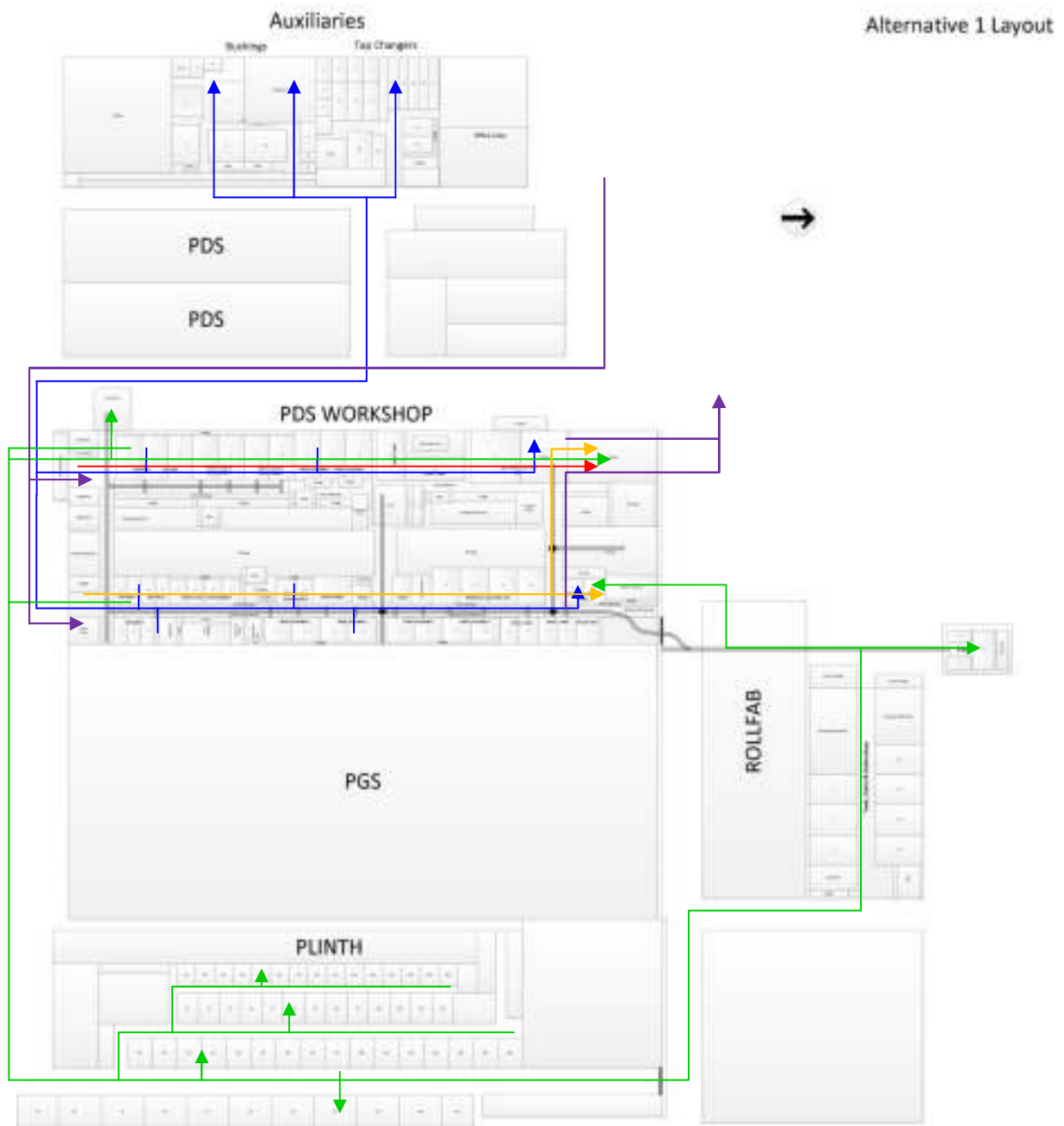


Figure 35: Alternative 1 material flow

### 12.3. Alternative 2

Alternative 2 Layout

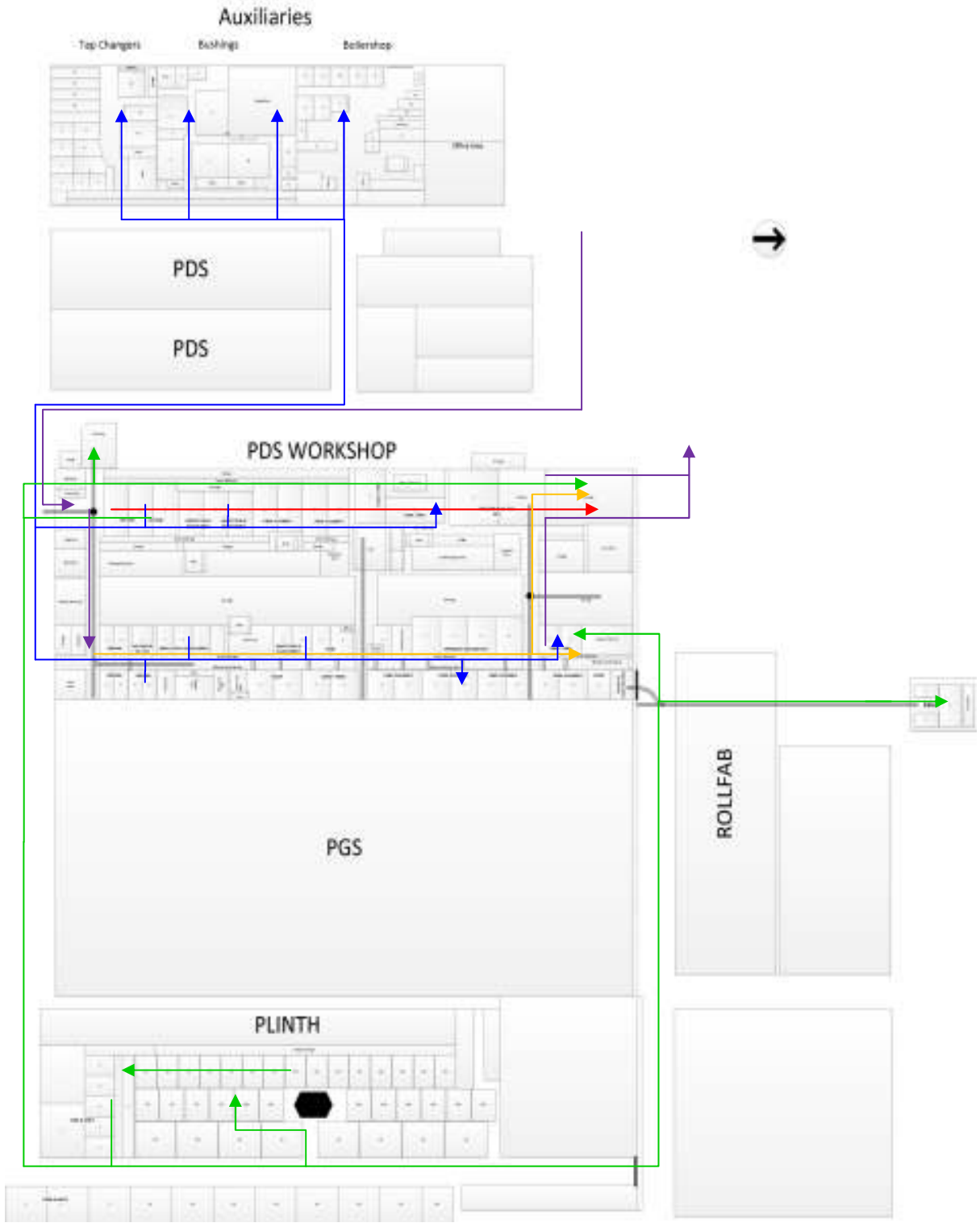


Figure 36: Alternative 2 material flow

## 12.4. Legend for Material Flow







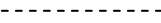
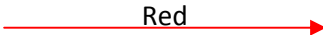

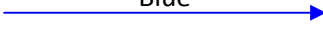

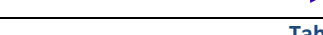
	Turn Style
	Person Crossing
	Bogie Rail
	Security Gate
	Tower Crane
	North
	Fence
 Red	600 ton Transformer Active Part Movement
 Yellow	200 ton Transformer Active Part Movement
 Blue	Auxiliary Parts Movement
 Green	Tank Movement
 Purple	Receiving and Dispatching of Transformers

Table 11: Legend for material flow

## 13. Material Handling Options

There are many options to consider when developing the material handling system. Small changes could make a big difference in the output of the company.

- Standardize the transport of auxiliary parts. Currently every set of bushings or tap changers are moved in a customized manner because of the varying types of bushings or tap changers. The method should be standardized; this can be achieved by flexible material handling equipment. Meaning to have a single type of material handling equipment that will be able to transfer many different types of bushings or tap changers.
- Create a unit load for smaller parts for transformers. When un-tanking takes place collect all the relevantly small parts such as nuts, bolts and flanges in a single sealable container. Store this container until tanking takes place. These unit loads should be clearly marked and stored in a structured and practical manner.
- Use large forklifts for the transport of transformer tanks around the facility including to and from tank and parts, to and from the plinth, to and from the paint bay.
- Use a railway system to move transformer tanks around the facility in the same way as the previous point.

- Use an air cushion transport system to move transformer tanks around the facility in the same way as the previous point.
- Use a tractor and bogie system to move transformer tanks around the facility in the same way as the previous point.
- Pressurize the medium and large transformer clean condition areas. This will ensure that the clean condition areas stay as clean as possible.
- With the use of a pressurized clean condition area it should be ensured that pressure isn't lost in a drastic way. It may be necessary to implement a double door system. This system is where the transformer enters through one door with another closed in front of it. The first door closes and only then can the transformer enter the facility through the second door. The transformer exits in a similar way. The same type of system can be used for people entering and exiting the clean condition area. This system can often be seen as a safety measure in banks.
- Bays in the clean condition areas should be separated and closed off from each other to ensure that no damage is inflicted on neighbouring transformers. This is especially applicable in the large transformer active part bays.
- Hydraulic Jack systems will help to improve the loading and offloading of transformers.
- Use forklifts to move auxiliary parts within the workshops.
- Use the air cushion system that was previously discussed can be used within the workshops, for easy and effective flow of parts and transformers within the facility.
- Use a rail bogie system to carry tanks to and from the new paint facility and within the medium transformer aisle.
- Upgrade the current crane systems. The current system is old and slow, a modern system will improve the flow of materials. Especially the larger parts such as the active parts and the tanks.
- The single paint bay that is currently in use will not be enough to handle the increased throughput of 88 transformers per year, never mind the 130 transformers per year that is the final desired throughput. A second paint bay will be needed.
- Every bay should have its own tool storage area. This ensures the ease of tool management and ease for workers to get and use their tools.
- Extend the current bridge crane in the large transformer aisle to the outside of the workshop to make receiving and dispatching easier.

- Open the back doors to split receiving and dispatching. This also improves the material flow because there is no need for the transformer to go back to the receiving door.
- Create designated material handling aisles. These should be large enough for 3 ton forklifts to move through.
- Create designated walkways in the workshops. This will help improve the safety of employees in the facility. This will be achieved by the split in material handling and the personal walkways.
- Have a designated tank and parts repair area. This ensures that there will be no space taken within the workshops to do these repairs. This will coincide with a move of the boiler shop closer to the tank and parts area. The plinth will mostly be used for storage.
- The jib cranes should be utilized more.
- If the proposed new facilities are used then a gate should be opened at the plinth to ensure the easy movement of tanks to and from the new facilities.
- Use an 80 ton forklift for the movement of large transformer tanks.
- Use a 16 ton forklift for the movement of medium transformer tanks.

## 14. Recommendation

Rotek engineering Power Distribution services need to make changes to stay competitive. Management is planning to increase the throughput of the facility to 130 transformers per year within the next 5 years. PDS needs to modernize their material handling system to at least be on par with current industry standards.

### 14.1. Facility Layout and Material Flow

It is clear that there is a need for an extra paint bay. Without the extra paint bay the throughput can't increase to 88 transformers per year, not to mention 130 transformers per year. Therefore it will be needed to rent or buy the proposed new facilities at Rollfab. It is this author's opinion that the first proposed alternative would be the best alternative for Rotek engineering PDS. The alternative improves the material flow. Please see Figure 35: Alternative 1 material flow. The proposed facility will also coincide with changes in the amount of working bays.

The amount of working bays in the medium transformer workshop will need to be:

ACTIVITY BAYS	100 TRANSFORMERS; BAYS NEEDED
Un-tanking	2
Dismantling and Repair	15
Assembly	6
Vapour Phase	3
Tanking	1
Test	3

Table 12: Number of bays needed for the medium transformer aisle

There will be extra bays needed for storage of active parts or working materials. An additional 3 bays will be needed for storage or for receiving and dispatching.

The amount of working bays needed in the large transformer workshop will need to be:

ACTIVITY BAYS	30 TRANSFORMERS; BAYS NEEDED
Un-tanking	1
Active Parts	12
Vapour Phase	1
Tanking	1
Test	1

Table 13: Number of bays needed for the large transformer aisle

Again there will be extra bays for storage of active parts or working materials. Additional 4 bays will be needed for storage or for receiving and dispatching.

Other activity bays that will be needed throughout the facility include:

<b>ACTIVITY BAYS</b>	<b>130 TRANSFORMERS; WORKING BAYS NEEDED</b>	<b>130 TRANSFORMERS; STORAGE BAYS NEEDED</b>
Bushing Repairs	31	200
Tap Changer Repairs	17	75
Tank & Parts Repairs	3	25
Paint	2	-

**Table 14: Number of bays needed for other activities**

The amount of storage bays are to ensure that any transformers that come into the facility can be kept over a period of time. This will only be necessary if there is a great influx of transformers at a certain point in time.

It should be stated that these are theoretical estimates of the amount of working bays that will be needed. After implementation analysis should be done to determine if the amount of bays are correct or if alterations need to be made.

## **14.2. Material Handling**

Power Distribution Services need to update their material handling system. The material handling system is the first thing that can be changed. However these changes will be most effective with the changes in the facility layout and material flow.

### **14.2.1. Small Changes**

These changes are relatively small and would be relatively inexpensive. These are the changes that can and will make an immediate difference:

- Create a unit load for smaller parts for transformers. When un-tanking takes place collect all the relevantly small parts such as nuts, bolts and flanges in a single sealable container. Store this container until tanking takes place. These unit loads should be clearly marked and stored in a structured and practical manner. This will ensure no loss and replacement of small parts.
- Standardize the transport of auxiliary parts. Currently every set of bushings or tap changers are moved in a customized manner because of the varying types of bushings or tap changers. The method should be standardized; this can be achieved by flexible material handling equipment. Meaning to have a single type of material handling equipment that will be able to transfer many different types of bushings or tap changers. This is something that will be able to solve a major problem for PDS. This will take up some time of research and development but it is believed that the pay-off will be great.

- Bays in the clean condition areas should be separated and closed off from each other to ensure that no damage is inflicted on neighbouring transformers. This is especially applicable in the large transformer active part bays. This will help to minimize rework in the workshops.
- Use a tractor and bogie system to move transformer tanks around the facility, especially from and to tank and parts as well as the new Rollfab facilities. There will be a need for at least two tractors and two roads worthy bogies.
- Hydraulic Jack systems will help to improve the loading and offloading of transformers. These hydraulic jack systems will be used side by side with the tractor and bogie system and with the receiving and dispatching of transformers. There will be a need for two hydraulic jack systems.
- Every bay should have its own tool storage area. This ensures the ease of tool management and ease for workers to get and use their tools.
- Open the back doors to split receiving and dispatching. This also improves the material flow because there is no need for the transformer to go back to the receiving door.
- Create designated material handling aisles. These should be large enough for 3 ton forklifts to move through. The 3 ton forklifts can be used to move auxiliary parts to and from the auxiliary workshops. Three more 3 ton forklifts will be needed.
- Create designated walkways in the workshops. This will help improve the safety of employees in the facility. This will be achieved by the split in material handling and the personal walkways.
- The jib cranes should be utilized more.

### 14.2.2. Big Changes

These are the major changes that will be needed to improve the facility and to ensure the facility's ability to have a capacity of 130 transformers per year. These changes will be expensive.

- Pressurize the medium and large transformer clean condition areas. This will ensure that the clean condition areas stay as clean as possible. With the use of a pressurized clean condition area it should be ensured that pressure isn't lost in a drastic way. It may be necessary to implement a double door system. This system is where the transformer enters through one door with another closed in front of it. The first door closes and only then can the transformer enter the facility through the second door. The transformer exits in a similar way. This system will help to improve the amount of rework in the workshops due to faults caused by dust or dirt.
- Use an air cushion transport system to transport the transformer active parts through the workshops. This is an easy to use and efficient system that will improve the material flow within the facility.
- Extend the current bridge crane in the large transformer aisle to the outside of the workshop to make receiving and dispatching easier. This will decrease the amount of space needed within the workshop that is being used for this process. The space can be used for more workspace. Coinciding with this process will be the upgrade of the current crane systems.
- If the proposed new facilities are used then a gate should be opened at the plinth to ensure the easy movement of tanks to and from the new facilities. To ensure the ease of movement to the new facilities there will be a need to upgrade the roads that lead to those facilities.

## 15. Conclusion

Facility layout, material handling and material flow are three integral parts of facilities planning. You can't do one without considering the other two. Facility planning is a good method of optimizing the facility. This project will focus on the facility planning of the transformer workshops, namely the medium transformer aisle (workshop) and the large transformer aisle (workshop).

Firstly the current facilities, material handling and material flow were analyzed. It was determined that the current system would not be able to have a capacity of more than 88 transformers per year. The main goal of this project is to optimize the facility to have a capacity of 130 transformers per year, 100 of which is medium transformers and 30 large transformers.

It is this author's opinion that with the recommendations that the workshops will improve the facility's ability to have a capacity of 130 transformers per year. With the improvement of the facility and the improved throughput of the facility, Power Distribution Services will again be able to be a leader in the transformer repair market.

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### Special Thanks to:

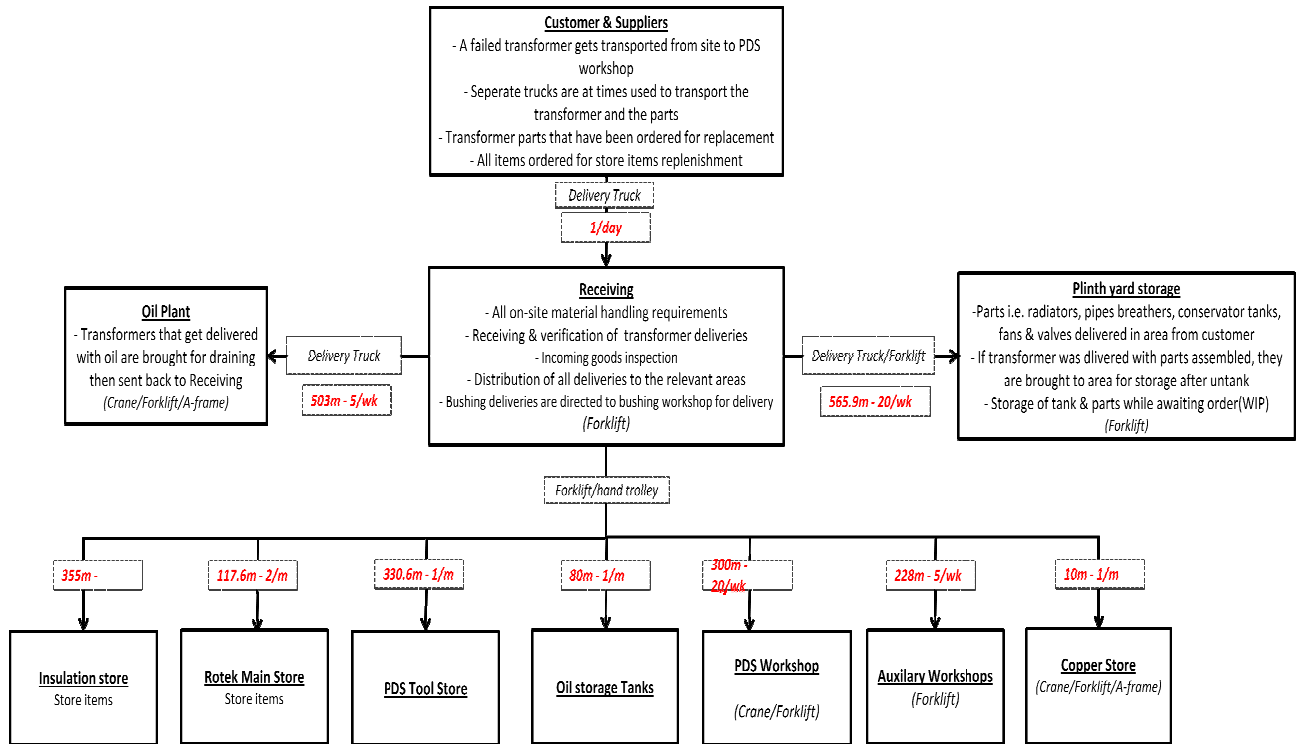
Erika Marais – Industrial Engineer at Rotek Engineering Power Distribution Services

Michael Judd – Fellow student, worked on the facility layout for PDS as vacation work

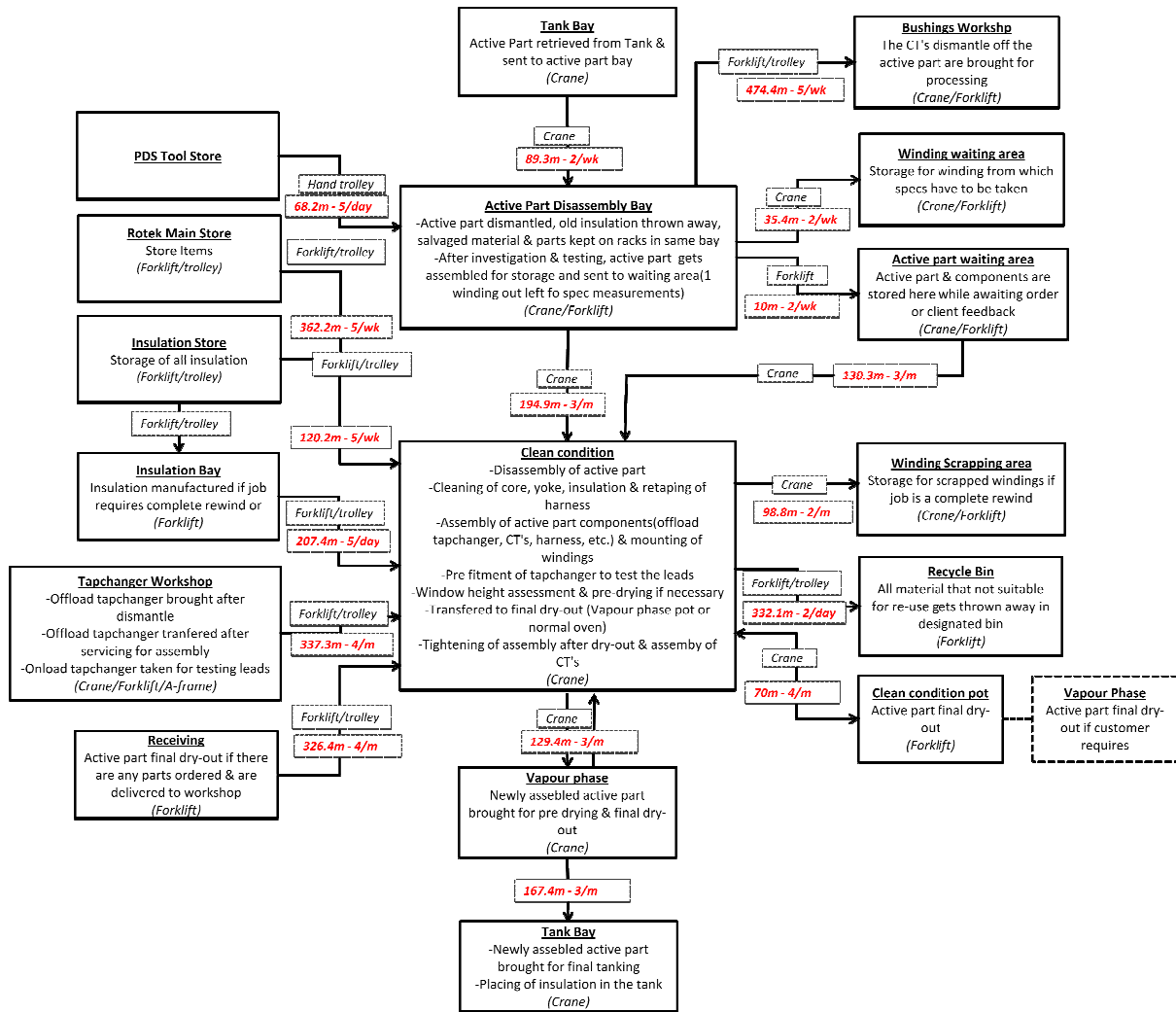
Nozindaba Tshabalala – Contact at PDS, especially helpful with material flow

# Appendix A: Material Flow Diagrams

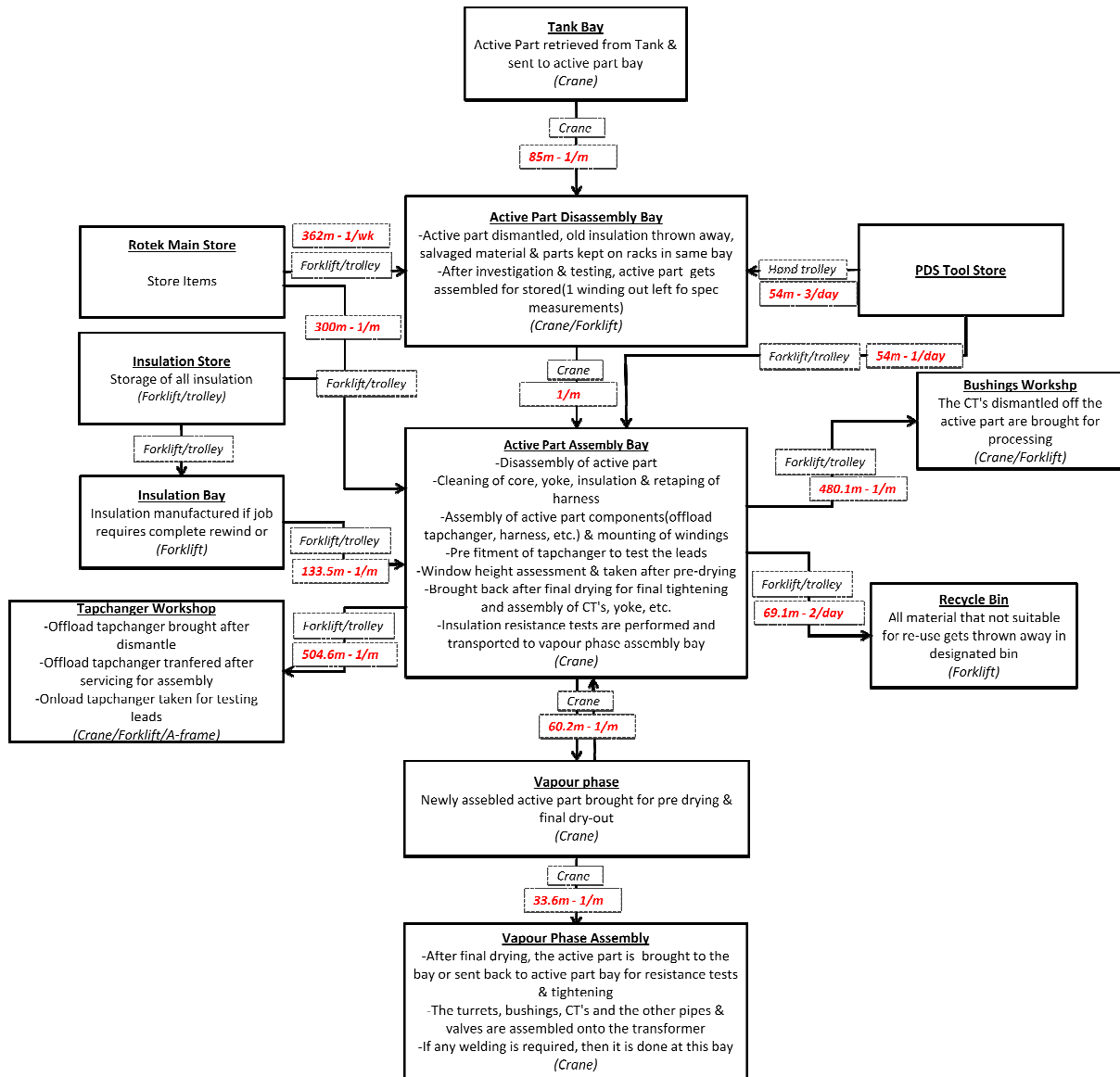
## Receiving and Dispatching



# Medium Transformer Active Part



# Large Transformer Active Parts



## Appendix B: Example of Job Studies

