

# ASSEMBLY LINE LAYOUT AND PROCESS OPTIMIZATION AT POWERTECH TRANSFORMERS

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by

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## **Executive Summary**

Powertech Transformers, located in Pretoria West, is one of the largest and sophisticated transformer manufacturing plants in the southern hemisphere. The variety of products manufactured is used by local authorities, mines, industrial plants, and the utility industry. The manufacturing plant has experienced problems with the productivity and efficiency of their active assembly area.

This project was aimed at optimizing the active assembly line layout and at improving the current process. The selection and implementation of the relevant industrial engineering tools and problem solving techniques helped to achieve this goal.

This document describes the situation at Powertech Transformers and how the implementation of systematic layout planning and lean manufacturing will achieve potential savings and improvements. These selected techniques have been directed at improving specifically the material flow and tool usage to ultimately optimize the efficiency and production effectiveness throughout the overall layout area.

The future state of Powertech Transformers has a more efficient flow of materials and operations and will ultimately improve the productivity of the area. The improvements will enable the operators and management to have more control over the process and to focus their attention on the quality of the operations and the products. It is expected that with more focus on quality that less products will be faulty, saving time and money.

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# 1. Background and Introduction

## 1.1. Company Profile

Powertech Transformers (previously known as ABB Powertech Transformers) is based in Pretoria West and is 80% owned by the biggest power-electrical group in Southern Africa, Power Technologies (Pty) Ltd. The remaining 20% is owned by Power Matla. The plant in Pretoria West is well equipped and one of the largest and sophisticated transformer manufacturing plants in the southern hemisphere and provides transformers to the African continent.

The variety of products manufactured by the company ranges from three-phase and single-phase units, auto-transformers, shunt reactors, rectifier transformers and power distribution products. Powertech Transformers uses standardized design elements and manufacturing procedures that make the production process more flexible. All the separate parts and materials used to build the transformers are custom made by Powertech Transformers to ensure that the final product is of the highest quality. The products are used by local authorities, mines, industrial plants, motor manufacturers and the utility industry.

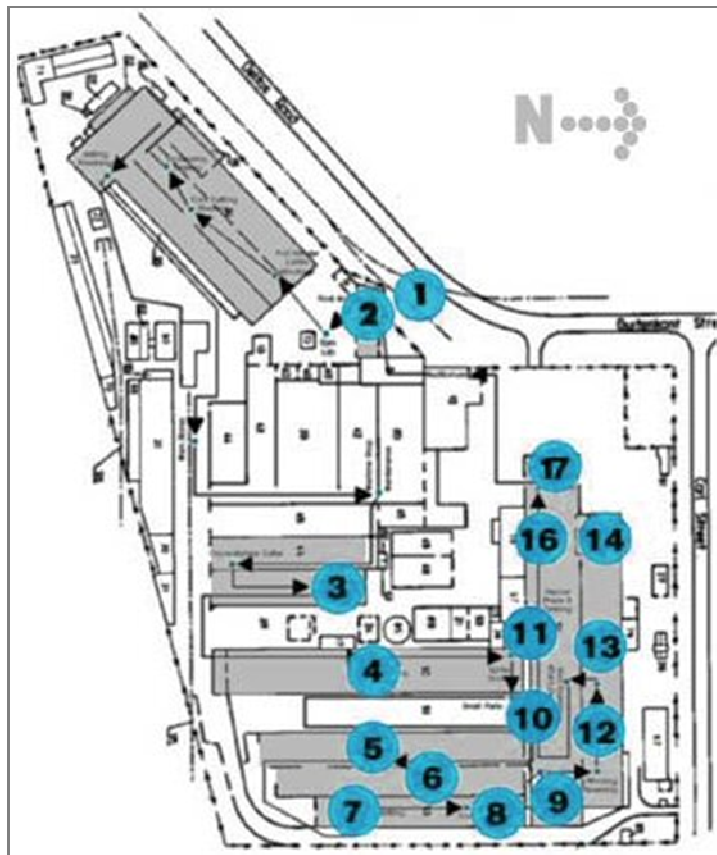


Figure 1.1: Layout of the Powertech Transformers Plant in Pretoria West

## 1.2. Project Introduction

Powertech Transformers manufactures all the individual parts for the power transformers. The company's experience allows them to apply flexible and well co-ordinated manufacturing processes to ensure that the power transformers are of the highest quality.

The plant is divided into several sections for each step of the manufacturing process (Figure 1.1). The active parts assembly area (Figure 1.2) will be the focal point in this project. This area consists of six assembly platforms/scaffolds where the individual power transformers are built. The power transformers are designed and manufactured to the customer specifications.



**Figure 1.2: Active Parts Assembly Area**

The iron cores are built in the stacking area. From there the cores are transported via the overhead crane to the active parts assembly area where it is loaded onto an available assembly platform (Figure 1.3). The assembly steps and activities are further discussed in appendix B. The output of the active parts assembly area is the finished assembled power transformer.

**Figure 1.3: Cores are transported via the overhead crane**



## **2. Problem Statement**

Powertech Transformers has identified that the current active parts assembly line's production output is less

than optimal. The problems that have been identified are:

- Production is behind schedule
- Necessary tools to perform operations are not readily available
- There is no demarcation of storage areas for the

tools and materials used

- Poor housekeeping of the area

Improvements need to be focused on increasing the efficiency and effectiveness of the production process in the active parts assembly area.

## **3. Project Aim**

The aim of this project is to create an optimal work area in the assembly line that will enable the workers to perform their duties without any obstructions or delays and thus increase the production activity.

Goals of the project:

- Define and establish the current layout of the active parts assembly area
- Optimize this layout area by implementing lean manufacturing techniques
- Optimize the housekeeping
- Identify the tools currently used and needed for the assembly process
- Improve the identification, usage and storage of the tools and materials

- Create a visible and safe work area

#### **4. Project Scope**

The project scope is as follows:

- Physical measurement and development of the layout area and all the fixed workstations and machines in the assembly area
- A study of the workers and the procedures they follow will also be done to get an understanding of the flow of the process
- Conceptual designs of the layout area with improvements
- Improving the tool usage of the individual workers, each platform, and the assembly line
- Improving the housekeeping of the area
- Establishing a process flow diagram
- Evaluation and selection of best alternative layout

The main objective is to increase the profitability of the company by minimizing the costs and maximizing the efficiency and effectiveness of the process and quality of the products.

#### **5. Deliverables**

The deliverables of this project are the applicable industrial engineering tools and techniques that are used to improve the quality and efficiency in the assembly area. They are listed as follows:

- Fish Diagram to determine the causes and effects of the problems
- Gantt chart for project planning and control
- Flow diagram
- Operation Analysis: What, Why, How, Who, Where, When?
- Chart relationships
- Activity Relationship Diagram
- Alternative Layout Evaluation
- Training Approaches
- Lean Manufacturing
- Housekeeping (5S)
- Critical Path Method
- Systematic Layout Planning (SLP)
- Total Quality Control
- Facilities Planning
- Tool analysis
- JIT (Just-in-time) analysis
- Kanban pull-system

These techniques will be directed at identifying and improving the problem areas to create a work environment that is operating efficiently and productively.

## 6. Literature Review

### 6.1. Overview

The literature review is essential for the gathering of information that is relevant and useful to this project. The analysis of the information and data collected will ultimately provide a better understanding of the existing problems in the active parts assembly area and how various methods can be used to solve these problems. The focus point is to create an optimal solution from the different industrial engineering techniques that will reduce the costs and improve the productivity of the assembly area.

The following sources were used for this information gathering:

- Observations by the student
- Discussions with the workers
- Discussions with Mentor
- Textbooks
- Journals
- Previous studies
- Internet

Powertech Transformers is currently struggling to make profit on the active parts assembly line. The average production time and costs for large and small power transformers are shown in Table 1.

	Small Transformers	Large Transformers
<b>Production Cost</b>	R4 million	R18 million
<b>Production Time</b>	14 weeks	26 weeks

**Table 1: Production Times and Costs**

Interest costs and penalty costs are paid for every day that the product is late for delivery. The interest is currently taken on a fixed rate of 12.5% (subject to change). The penalty rate per day can vary between 0.1% and 10% of the product value, as stipulated in the contract. If a small transformer is 5 days late and the penalty rate is 10% per day; the total costs lost would be R5480 per day penalty cost and R6850 interest cost.

It is clear that a great amount of money will be lost if the production is behind schedule. The factors responsible for the late product delivery time are listed in order of most occurrences:

1. Absenteeism of operators
2. Poor performance
3. Poor quality
4. Engineering changes
5. Late supply from suppliers
6. Breakdowns of machines

According to Niebel et al (2003) “the objective of the manufacturing manager is to produce a quality product, on schedule, at the lowest possible cost, with a minimum of capital investment and a maximum of employee satisfaction.” A study of possible techniques is done to determine which methods will produce this end result.

The techniques under consideration for the problem solving are shown in the breakdown diagram in figure 2 and are further discussed in this literature study.

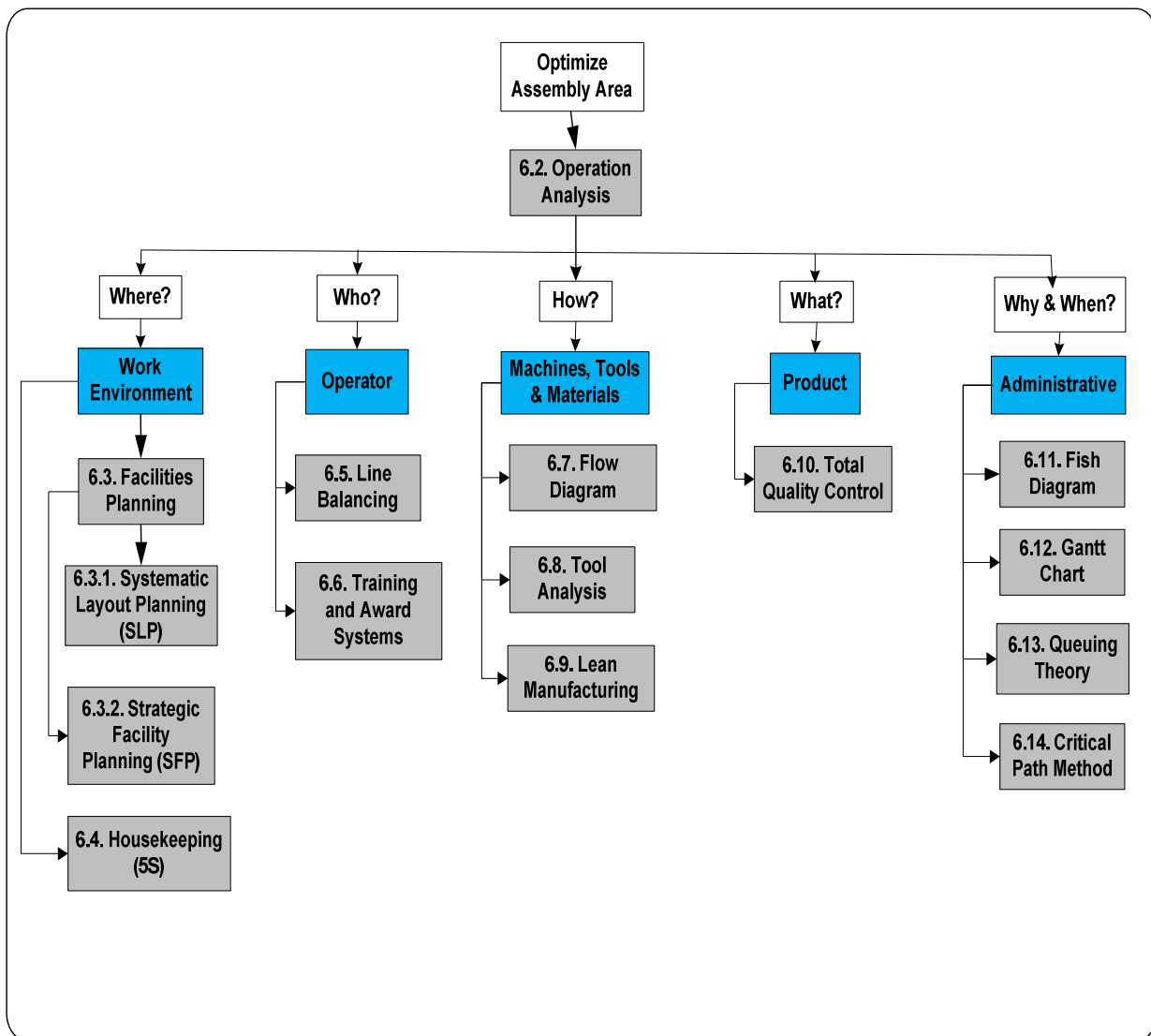


Figure 2: Breakdown Structure of Literature Review

## 6.2. Operation Analysis

Operation analysis is an effective method used by many methods analysts in their quest to improve work centres and increase productivity in productive and non-productive sections of an organization. The questioning approach is used in all areas of the organization to help obtain all the relevant facts. Niebel et al (2003) states that “practically all operations can be improved if sufficient study is given to them.”

The six primary questions asked to gather facts are what, why, how, who, where and when. Nine systematic approaches have been developed to assist with the analyzing of the facts gathered.

These nine approaches are:

- Operation purpose
- Part design
- Tolerances and specifications
- Material
- Manufacture sequence and process
- Setup and tools
- Material handling
- Plant layout
- Work design

## 6.3. Facilities Planning

Facilities planning help with the coordination of the organization, processes, products, facilities and customers in such a way as to achieve efficiency in the entire business. In the manufacturing sector it becomes more complex and difficult to facilitate the overall objective throughout the plant because of the multiple activities involved. Sule (1994) states that “planning is vital for the efficient utilization of available resources. “



A successful facility requires good planning and design. The following five steps is a basic approach to facilities planning:

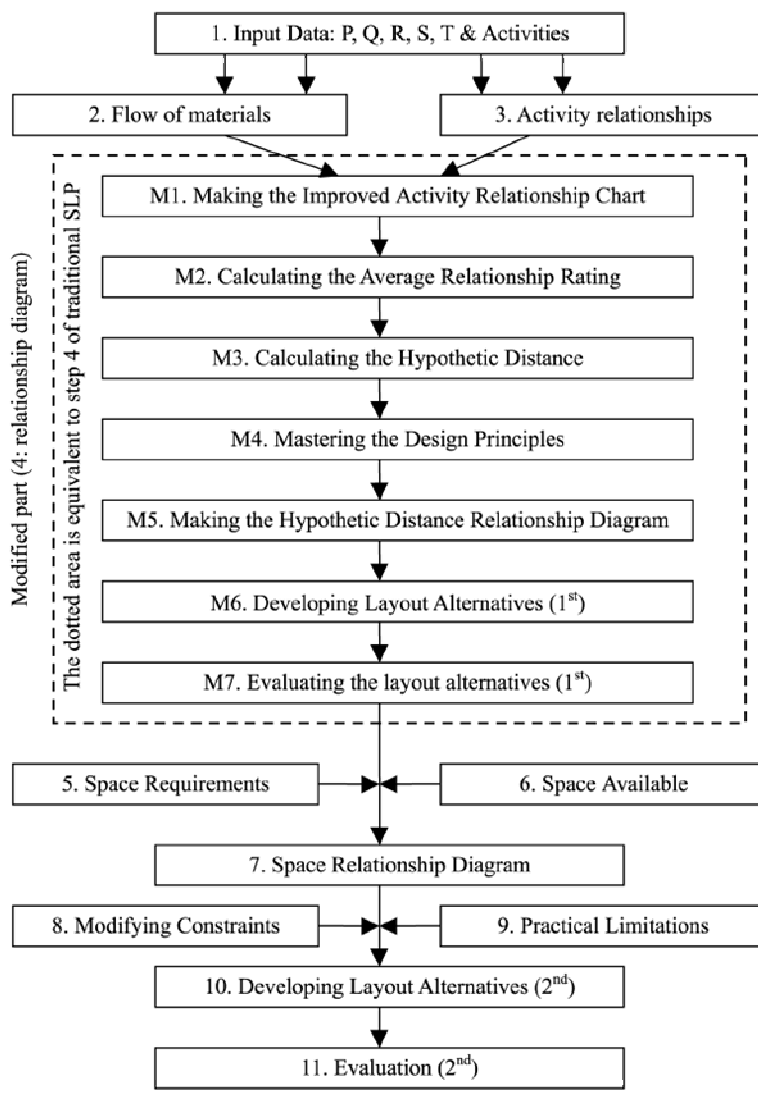
1. Establish clear goals of what the client want to accomplish with the facility.
2. Collect and analyze data about existing space standards
3. Create concepts of how to attain the specific goals.
4. Determine the costs associated with space, supports, schedule and quality.
5. Summarize the solution and use it to help with the evaluation of the

project design and construction.

**Figure 3.1: Evolution of Facilities Planning**

### 6.3.1. Systematic Layout Planning (SLP)

Systematic Layout Planning is a tool developed by Muther that provides the industry with layout design guidelines. Niebel and Freivalds (2003) state that “the goal of SLP is to locate two areas with high frequency and logical relationships close to one another.” Figure 3.1 depicts a modified version of Muther’s SLP procedure (Chien, 2004).



**Figure 3.2: The modified SLP procedure**

#### SLP Procedure:

The input data contains information regarding the P (product), Q (quantity), R (route), S (support), T (time), and production activities.

The relationship diagram is developed to show the degree of importance of having certain work centres located near or next to other work centres or activities. The information needed for the relationship diagram can be gathered from the input data, from-to-chart and activity relationship charts.

The from-to-chart depicts the quantitative functional interactions between areas (flow of materials) and the activity relationship chart shows the activities (like material handling) taking place between the certain work centres.

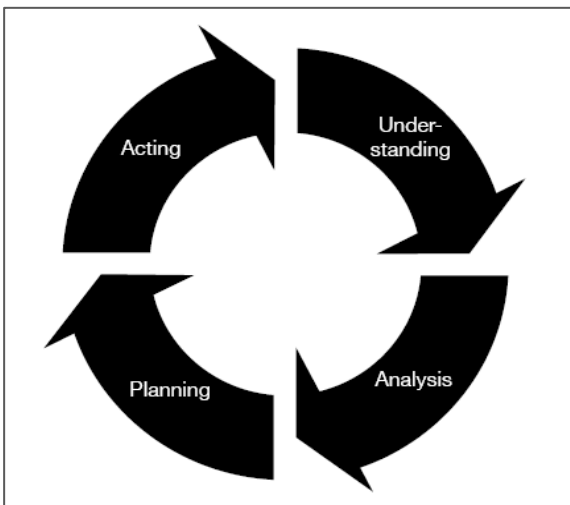
The space limitations will guide with the development of possible layout alternatives. Systematic layout planning uses adjacency-based scoring to develop the layout alternatives. Trial and error will help with the selection of a satisfactory layout.

See appendix C for a detailed summary of the SLP procedure.

### 6.3.2. Strategic Facility Planning (SFP)

Strategic facility planning is a proactive process that creates strategic facility goals that is in line with the organization's strategic business objectives.

The four-step SFP process (figure 3.2) is used to assist in the in-depth study of the existing facility and helps with the development of an improved facility plan that will give the organization a competitive advantage.



#### SFP Process:

##### **Understanding**

A balanced scorecard can be used to understand the long term mission and goals of the organization. The understanding of the current business demographic and available resources is essential for SFP.

##### **Analyzing**

Brainstorming, scenario planning, SWOT analysis and SLP can be used to analyze the different elements of SFP: employees, processes, organization structure, government regulatory requirements, market position, product volumes and capacity of resources.

**Figure 3.2: Four-step SFP process** ([http://www.ifma.org/tools/files/SFP\\_WhitePaper.pdf](http://www.ifma.org/tools/files/SFP_WhitePaper.pdf))

##### **Planning**

The plan development phase creates the course of action that will support the organization's goals in the long term. IFMA's steps in setting up the plan consist of:

- Documenting primary objectives
- Evaluating the factors that are critical for success
- Risk analysis to find maximum value
- Developing alternatives
- Developing a process for marketing the recommended SFP to gain approval
- Obtain financial and other relevant approvals
- Launch the action phase

##### **Acting**

The implementation of the SFP plans can be done by different projects being launched. Feedback on the success and failures of these projects will help to continuously improve and update the plans.

IFMA, in its "Strategic Facility Planning: A white paper, 2009" report, defines strategic facility

planning as: “The process by which a facility management organization envisions its future by linking its purpose to the strategy of the overall organization and then developing goals, objectives, and action plans to achieve that future. The result of the strategic facility planning process is the strategic facility plan.”

The Strategic Facility Planning process model is shown in detail in appendix D.

## 6.4. Housekeeping (5s)

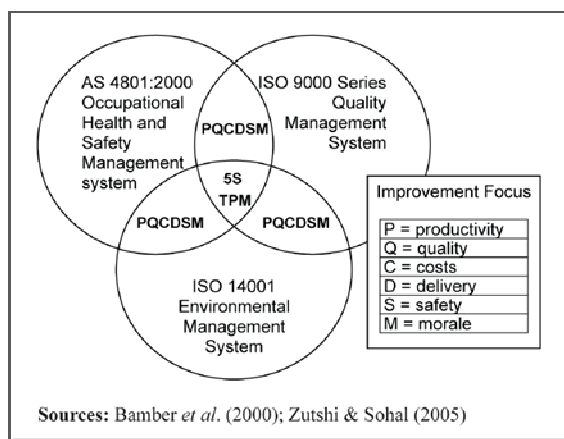
According to Jacobs et al (2009) “good housekeeping entails keeping only necessary items in the work area, that there is a place for everything and that everything is clean and in a constant state of readiness. When good housekeeping is in place tidiness, quality control, safety and pride will result at the end of the day.”

The 5s methodology is based on the 5 Japanese acronyms:

- *Seiri* – Organisation
- *Seiton* – Neatness
- *Seiso* – Cleaning
- *Seiketsu* – Standardisation
- *Shitsuke* – Discipline

The aim of 5s is to embed these values into the workplace.

Housekeeping is the western term used for work place organisation or 5s. It is a value driven business model that can be seen as the initiating point within lean manufacturing. The primary objective of 5s is to create a safe and healthy work environment where productivity can be increased. The strategic priorities of productivity, quality, costs, delivery, safety, and morale are depicted in figure 4.



**Figure 4: Strategic priorities of 5s**  
(Gapp *et al* (2008))

Benefits from implementing 5s are:

- Reduced workload and human errors
- Simplified processes
- Maximized effectiveness
- Increased quality
- Enhanced level of worker morale

- Healthier and safe work environment
- High level of autonomy

5s is a stepping stone to an integrated management system, but it can only be achieved through total participation and high levels of managerial decision making. Some activities that support the 5s implementation is:

- U-shaped cells and cell layout
- Visual controls
- Setup reduction
- Ergonomic improvements
- TPM
- Pull Systems (Kanban)
- WIP reduction
- Poka-Yoke Device

## 6.5. Line Balancing

Line balancing determines 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 most common objective of line balancing is to maximize the capacity utilization of the line and minimize the flow time.

The steps of performing line balancing by Jacobs et al (2009) are as follows:

- Draw a precedence diagram which depicts the order in which tasks must be performed.
- Determine the workstation cycle time (C):

$$C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

- Determine minimum number of workstations required (N):

$$N = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$$

- Select primary rules by which tasks are to be assigned to workstations.
- Assign tasks, one at a time, to the first workstation until the sum of task times are equal to the workstation cycle time. Repeat process for rest of workstations until all tasks are assigned.
- Evaluate efficiency of the balance :

$$\text{Efficiency} = \frac{\text{Sum of task times (T)}}{\text{Actual \# of workstations} \times \text{Cycle time}}$$

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

## 6.6. Training and Award Systems

(Jong and Hartog, 2007) states that “one way for organizations to become more innovative is to capitalize on their employees’ ability to innovate”. The management of personnel requires a high level of people management skills. It is important to have employees who are trained and motivated as it will directly impact the quality of the product and productivity of the organization.

A study (Jong and Hartog, 2007) shows that there are 13 behaviours that a leader can undertake to promote innovation in the workplace:

- Innovative role-modelling
- Intellectual stimulation
- Stimulating knowledge diffusion
- Providing vision
- Consulting
- Delegating
- Support for innovation
- Organizing feedback
- Recognition
- Rewards
- Providing resources
- Monitoring
- Task assignment

Employee–employer factors that influence the environmental performance of the organization are shown in figure 5.

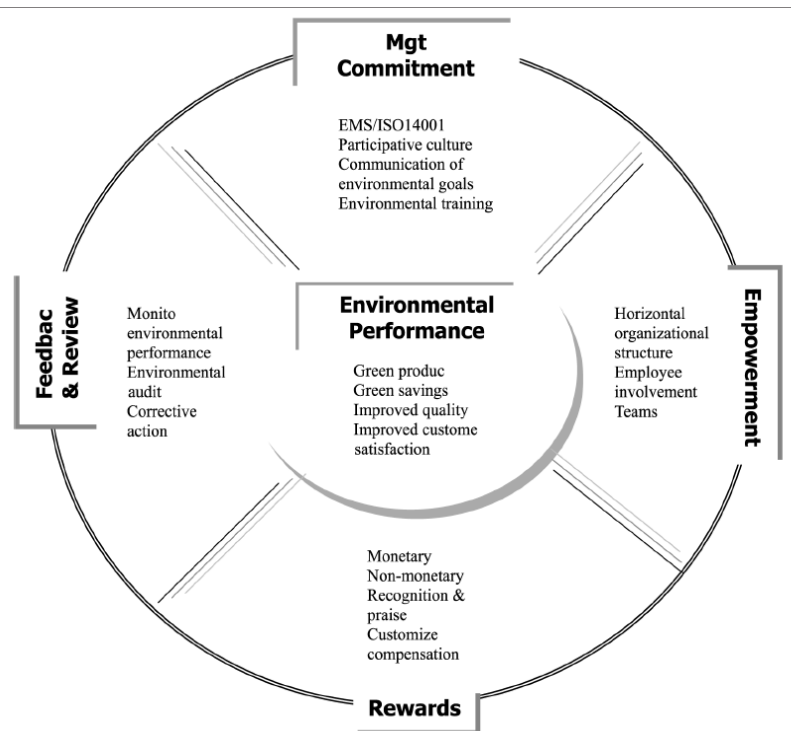


Figure 5: Environmental Performance factors

## 6.7. Flow Diagrams

The flow diagram provides the most relevant information of a manufacturing process. It is a graphic depiction of the movement of materials from one activity to the next.

The flow pattern of the materials and tools can be drawn on an existing layout plan of the plant area. The direction of flow is represented by an arrow. Departments or areas of importance

can be referenced by numbers on the diagram. Flow diagrams facilitate with the elimination and reduction of any hidden costs associated with a specific activity of the process. Traffic congestion areas and backtracking of materials will be made visible on the flow diagram, and can assist in the development of an optimal plant layout alternative (Niebel and Freivalds, 2003).

Bottlenecks can also be identified on a flow diagram. A bottleneck is a resource that limits the capacity of the process and can thus be seen as the pacesetter of the flow rate in the manufacturing system. Improved bottlenecks will lead to an improved system.

## **6.8. Tool Analysis**

According to Niebel et al (2003) the amount of tooling that is most advantageous depends on:

- The production quantity
- Repeat business
- Labour
- Delivery requirements
- Required capital

Poor planning and inefficient tooling leads to increased setup times and costs. A tooling evaluation checklist can be used to determine the amount and state of the current tools and which tools are needed.

Standardized equipment and tooling should be used as far as possible. Tool analysis determines the effectiveness of certain tools and their specific tasks. It is important to make sure that the correct tooling is used for the correct job so that the quality of the product will not be affected.

## **6.9. Lean Manufacturing**

Lean manufacturing was developed in Japan with the main goal of improving quality and productivity by eliminating waste and by respect for people.

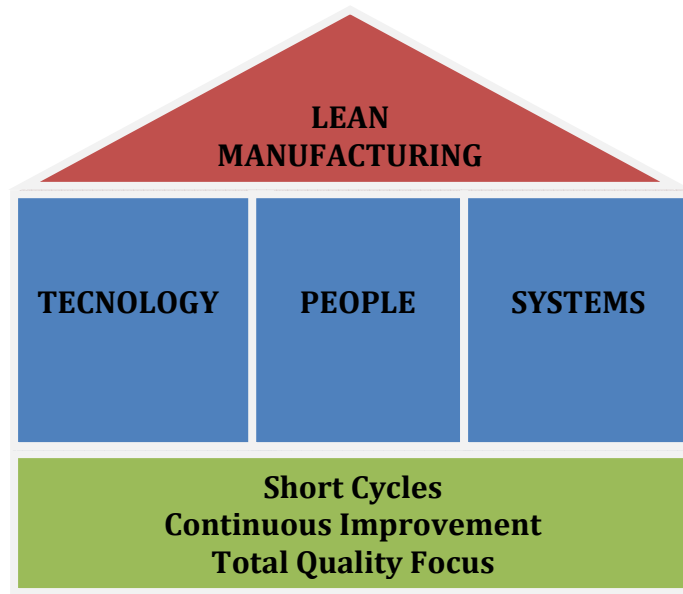
Fujio Cho has identified seven types of wastes that need to be eliminated from the supply chain:

1. Overproduction
2. Waiting
3. Transportation
4. Excess inventory
5. Over-processing
6. Unnecessary motion
7. Defects

The Toyota Production System led the way to lean production by using integrated activities to achieve high volume and quality products. A graphical depiction of lean manufacturing and its components are shown in figure 6.

Some lean manufacturing tools and techniques used in the industry are:

- Cellular management – rearrangement of tools, workers and workstations to eliminate waste
- JIT production – producing what is needed when needed
- Kanban system – card is used as signalling device to maintain JIT
- Kaizen – continuous improvement of machinery, materials, tools, methods and labour utilization through the suggestions and ideas of company teams
- Minimized setup times
- Uniform production flow/ production smoothing – keep production level as constant as possible
- Focused factory networks
- Quality at the source – do it right the first time
- Poka-yokes – preventing mistakes from becoming defects
- Standardization of work
- Total productive maintenance – preventive maintenance, corrective maintenance and maintenance prevention



**Figure 6: Summary of lean manufacturing**

## **6.10. Total Quality Control**

Total Quality Control seeks to eliminate/ reduce any causes of production defects and variations by using statistical quality control techniques. It was developed from the concept

of quality circles, where problem solving groups were formed consisting of people from different departments. The group then aimed to solve the problem that was responsible for certain defects. Kaizen is central to total quality control. In order for the product to be of good quality the design, functional/operating, environmental, safety, and reliability requirements must all meet the original specifications.

### 6.11. Fishbone diagram (Ishikawa)

The fishbone diagram is used to determine the primary and secondary causes of a certain event/problem. These causes can be grouped into six major categories: people, methods, machines, materials, measurements and environment. Other relevant categories can also be used. Figure 7 is a graphical representation of how the Ishikawa diagram works.

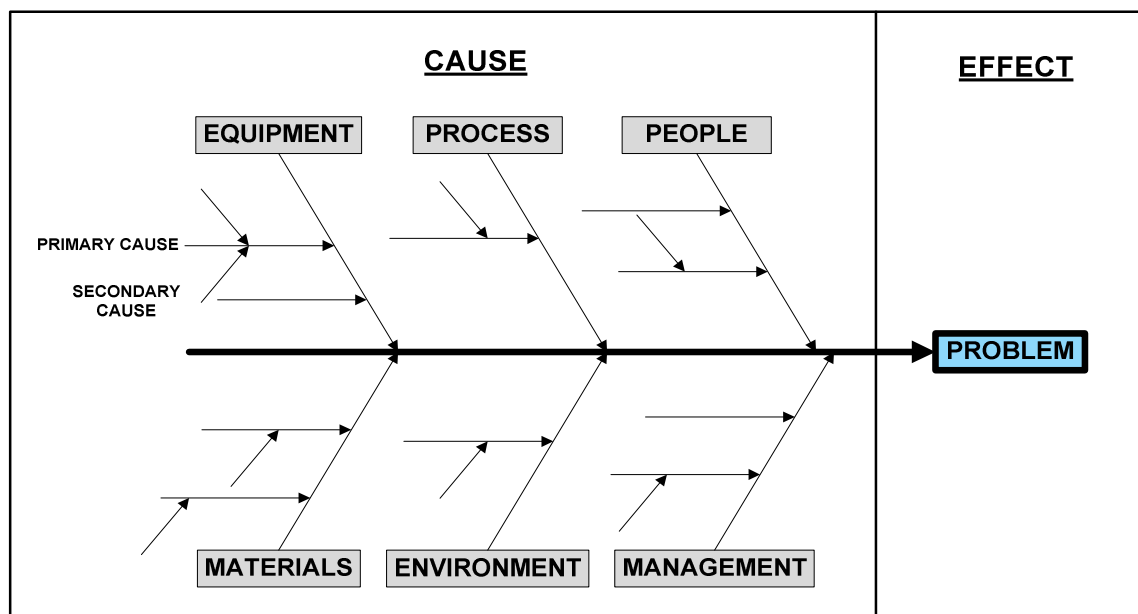


Figure 7: Fishbone diagram

### 6.12. Gantt Chart

The Gantt chart assists with the planning of the project schedule. It shows the starting, finishing, and other relevant dates. The project is broken down into the different activities that must be performed by using a work-breakdown structure. These activities are listed and scheduled on the Gantt chart. Schedule updates and percent-complete shadings show the status of the project. The data gathered from the Gantt chart will assist in the prevention of running behind schedule.

### 6.13. Queuing Theory

Mathematical models have been developed to describe and determine queues. Queues occur when there are a limited service capacity and the flow of arriving customers/ products are more than the capacity. Queuing models can assist with the development of an

“economic balance between waiting times and service capacity” according to Niebel et al (2003).

There are four characteristics of queuing problems:

- The arrival rate
- The service rate
- Number of servers
- Queue discipline, ex. FCFS discipline (first come, first served)

Some systems follow a Poisson arrival order. In this case there exist five possible categories, each with their own equations: (Niebel et al (2003))

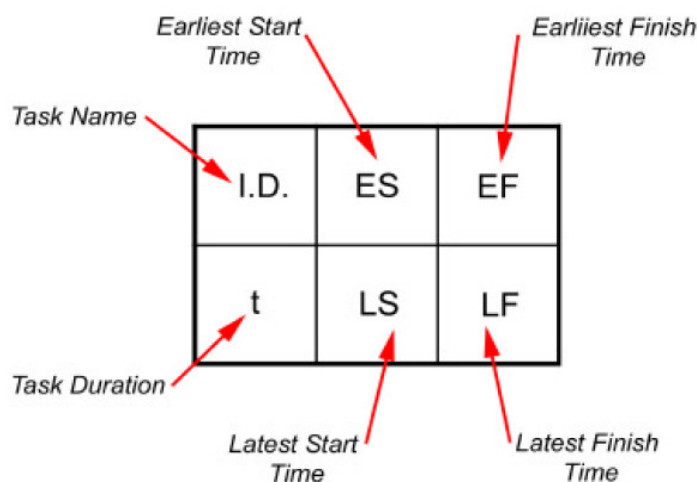
1. Any service time distribution and a single server
2. Exponential service time and a single server
3. Exponential service time and finite servers
4. Constant service time and a single server
5. Constant service time and finite servers

## 6.14. Critical Path Method (CPM)

Critical path method is a planning tool that shows the optimum way of achieving some predetermined goal. CPM helps to determine which activities are critical and must be completed first before the next activities can start, and it determines the duration period of the project. Information regarding the costs of activities can help to determine the most economic way to speed up a project if it is necessary.

CPM can only be done once all the individual activities of a project are predetermined.

The method used for CPM is called the critical path diagram or the activity-on-arc (AOA) diagram. Each activity is represented by the box shown in figure 8 with the relevant information as indicated. The activities are graphically connected in the order in which they take place. The different paths to the end result can be identified on the diagram. The longest path is known as the critical path, and it represents the minimum time required to complete the entire project.



**Figure 8: Activity box** (Source: <http://hspm.sph.sc.edu/Courses/J716/CPM/CPM.html>)

## **6.15. Selection of Appropriate Methods, Tools and Techniques**

The information gathered from the observations and the mentor highlighted the need for improvement in the overall layout, material flow, tool efficiency and availability, and worker performance. The above mentioned tools and techniques have certain aspects as to solving these problems.

The most important tools that will be used in this project are:

- Fishbone diagram (problem identification)
- Systematic layout planning (improved and efficient layout)
- Flow diagram (improved flow of materials)
- Lean manufacturing (waste elimination)
- Tool analysis (efficient tooling)
- Training and reward incentives (worker motivation)

## **7. Data Gathering and Analysis**

### **7.1. Overview**

The wastes need to be identified and removed from the active assembly line in order for the productivity to increase. The fishbone diagram was used to determine the causes of the assembly line problems and the effects it has on the system (appendix E).

From the fishbone diagram the following wastes have been identified:

- Time spent waiting for materials to arrive
- Time spent trying to find the correct tooling
- Distances travelled to find the materials and tooling
- Unnecessary motion of workers
- Defective product occupy platform/ scaffold that causes delays in the assembly area as the following jobs cannot be started
- Defects occur because of poor quality and performance of operators
- Possible production time wasted as a result of absent employees

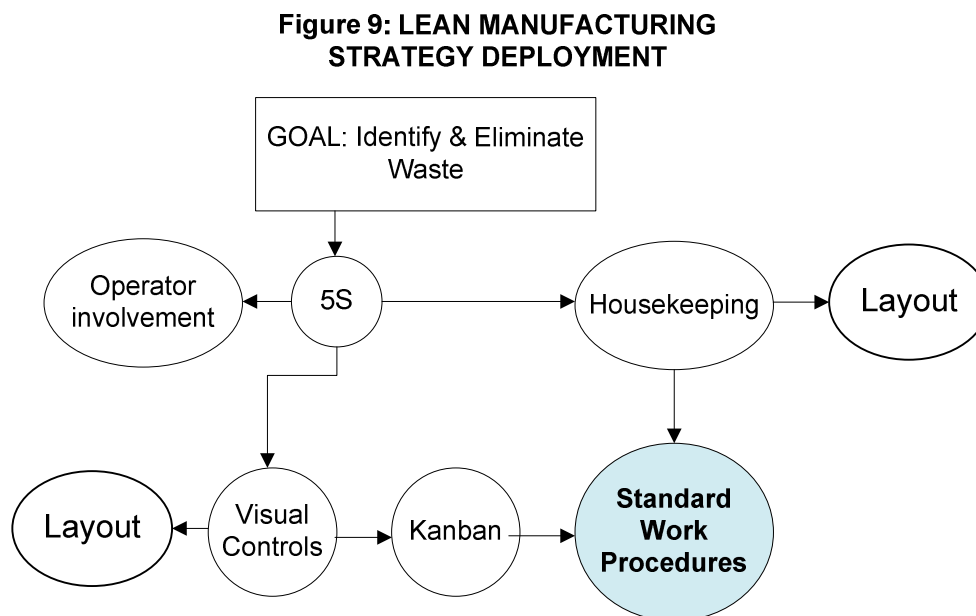
The factors responsible for the late product delivery time (and thus increased costs) can also be seen as waste. (Listed in order of most occurrences):

1. Absenteeism of operators
2. Poor performance

3. Poor quality
4. Engineering changes
5. Late supply from suppliers
6. Breakdowns of machines

Considering all the above mentioned waste, it can be concluded that the areas of immediate importance is the accessibility and availability of the materials and tools, a user-friendly layout, and worker morale.

Applying an interrelated lean manufacturing approach will help to solve these problems. Figure 9 shows the lean manufacturing strategy deployment that will be used.



After the wastes have been identified, the next step is to determine exactly what approach to take to try and minimize or eliminate the waste where possible.

This is summarized in figure 9:

- 5s is the initiating point for lean manufacturing
- It entails good housekeeping which means only the necessary items is in the work area, there is a place for everything and everything is clean and in a constant state of readiness
- Operator involvement is absolutely essential for 5s to be successful and will also result in a sense of pride, thus an increased worker morale
- Visual controls is an activity that support the 5s implementation
- Visual controls and housekeeping needs to be incorporated into the layout
- Kanban is a system designed to facilitate smooth operation

- Standard work procedures (that will explain the use of kanban and housekeeping) need to be written and adhered to by the entire operating team

The outcomes of this project will be a layout design that incorporates the easy usage and accessibility of tools and materials, and a standard working procedure in which the production process is summarized and available for use by all parties involved (especially management and the operators).

## 7.2. Layout Data

The plant layout was physically measured and drawn up in CAD to serve as a starting point for further improvements and implementations. This process aided in the data gathering for the project and created an in-depth understanding of the workings in the current assembly area. The initial layout of the plant can be seen in appendix F.

Following the systematic layout planning procedure, the subsequent data were collected.

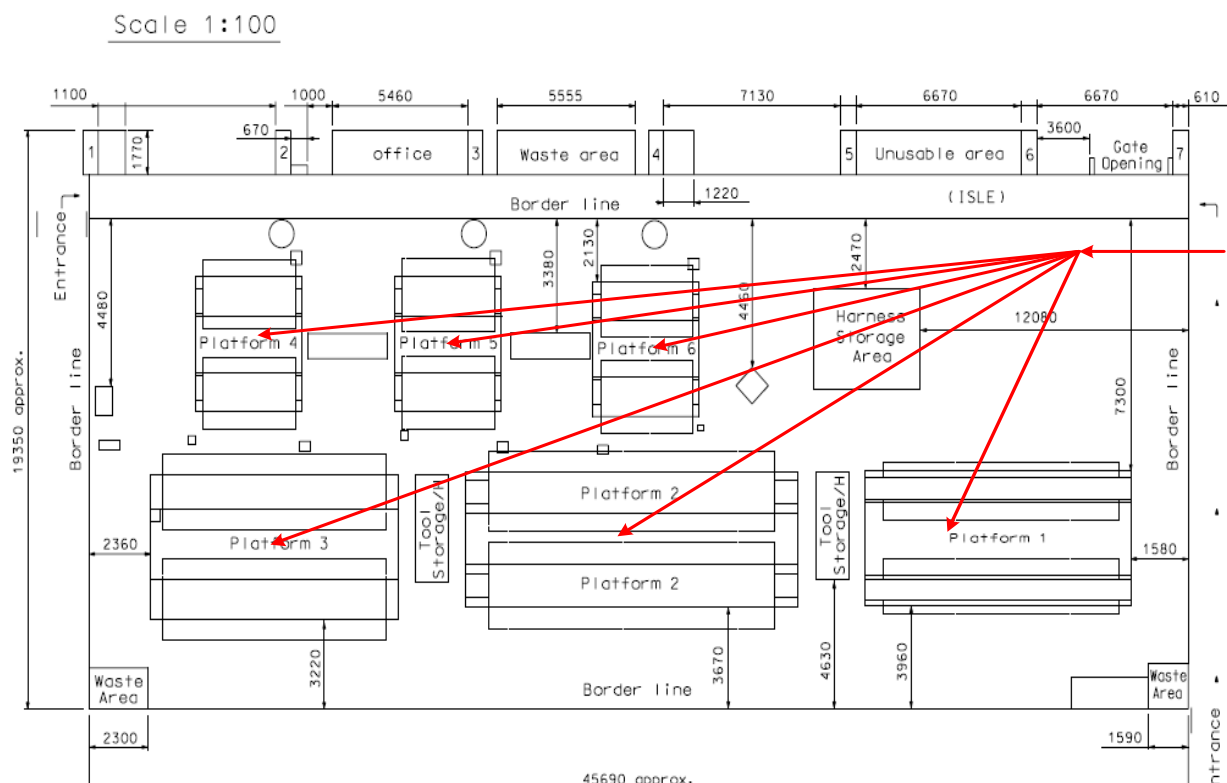
### 1. Input Data (product, quantity, route, support, time)

The critical path method (CPM) was used to draw the production flow of a transformer (the entire production process taking place including the assembly process) as well as indicate the path that is of high importance. See appendix G for the CPM and appendix B for the assembly process of a transformer.

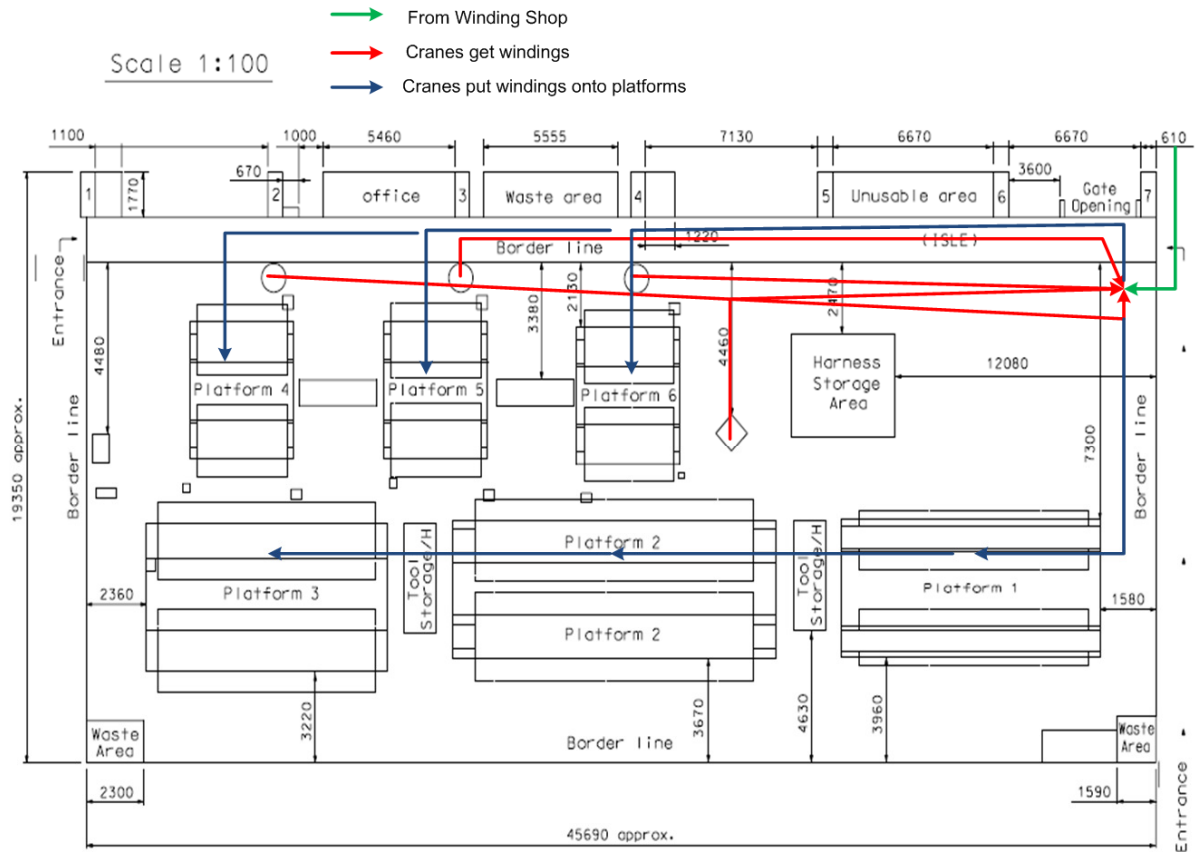
### 2. Flow of materials

It is important to mention that for the scope and budget of this project, a total renovation of the assembly area is not feasible. The scaffolds/ platforms are fixed measurements. The focus will therefore be on the location and layout of the materials and tools. The layout design will be made around the platforms.

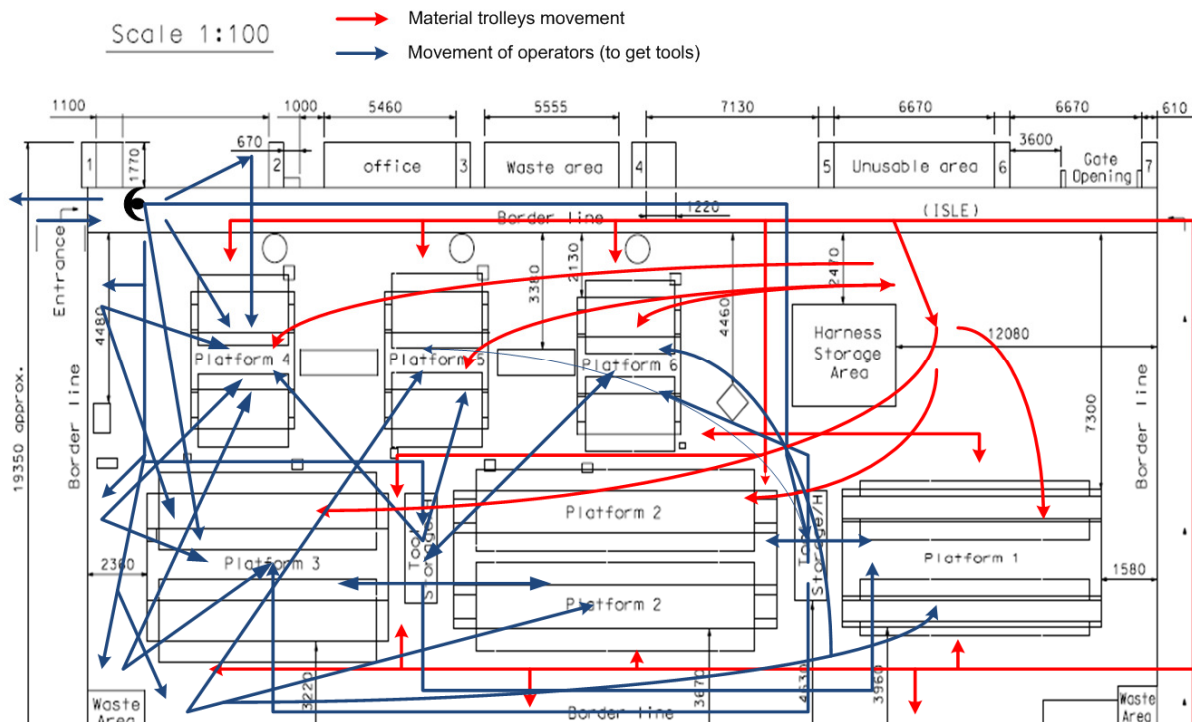
**Figure 10.1: Flow Diagram of the Cores being loaded onto the Scaffolds/ Platforms**



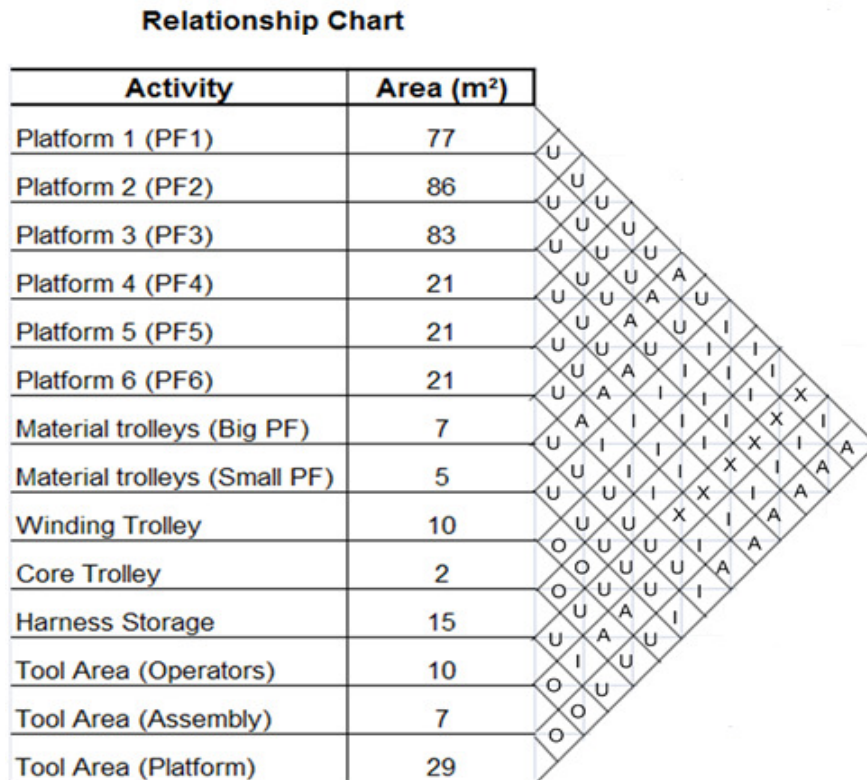
**Figure 10.2: Flow Diagram of the Windings**



**Figure 10.3: Flow Diagram of the Operators & Materials**



### 3. Chart relationships

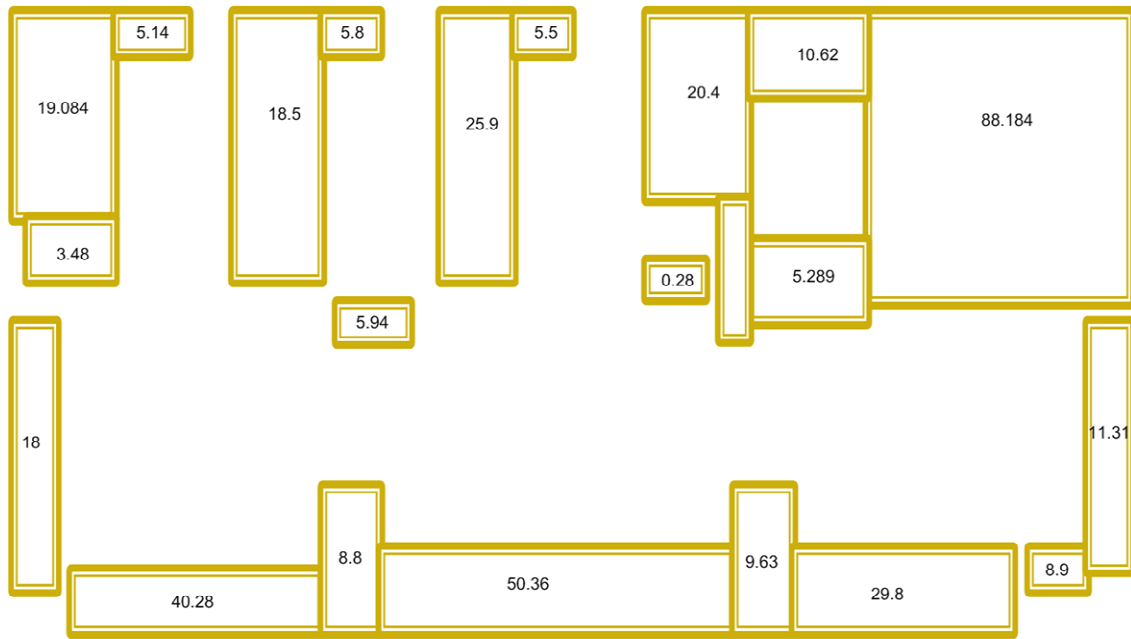


Vowel Letter	Value	Lines	Importance	Colour Code
A	4		Abnormally High	Red
E	3		Especially High	Orange/ Yellow
I	2		Important	Green
O	1		Ordinary	Blue
U	0		Unimportant	Uncoloured
X	-1		Not Desirable	Brown

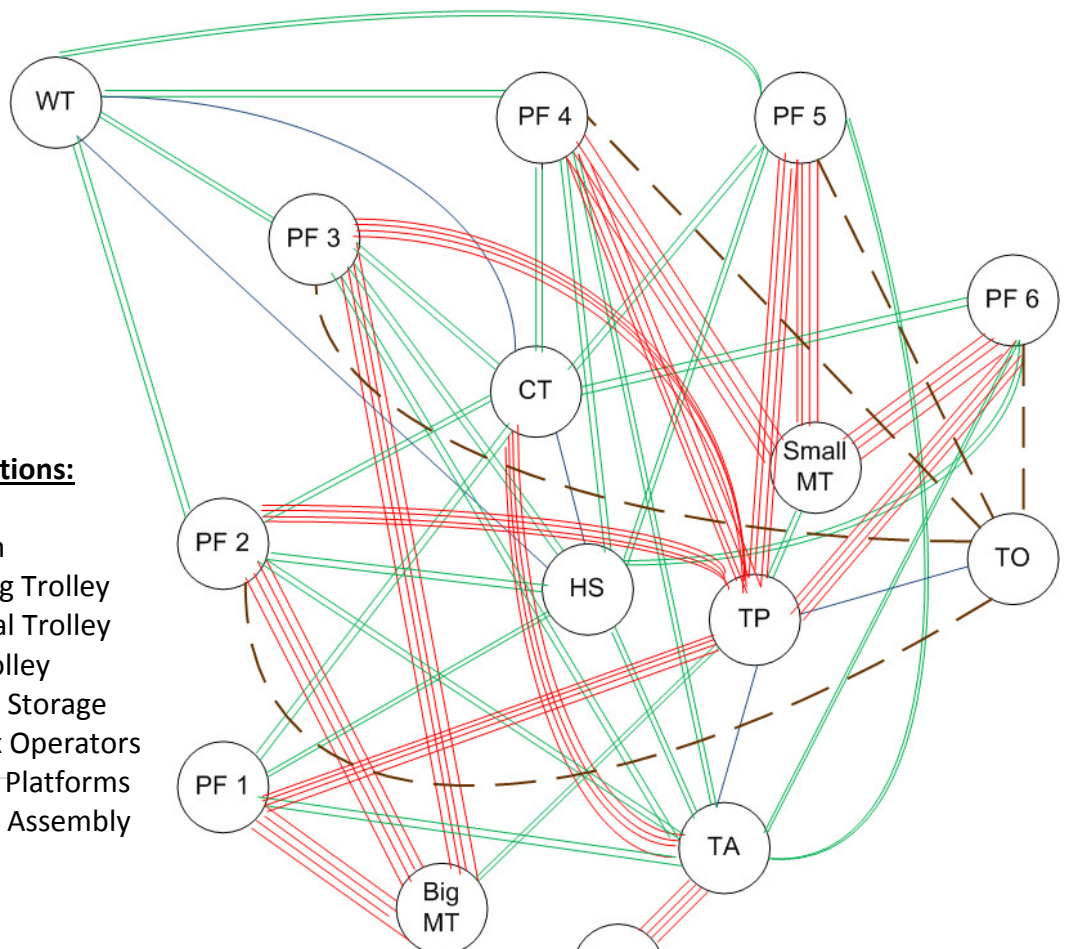
**Figure 10.4: SLP Relationship Ratings**



**Figure 10.5: Available space in meter per square**



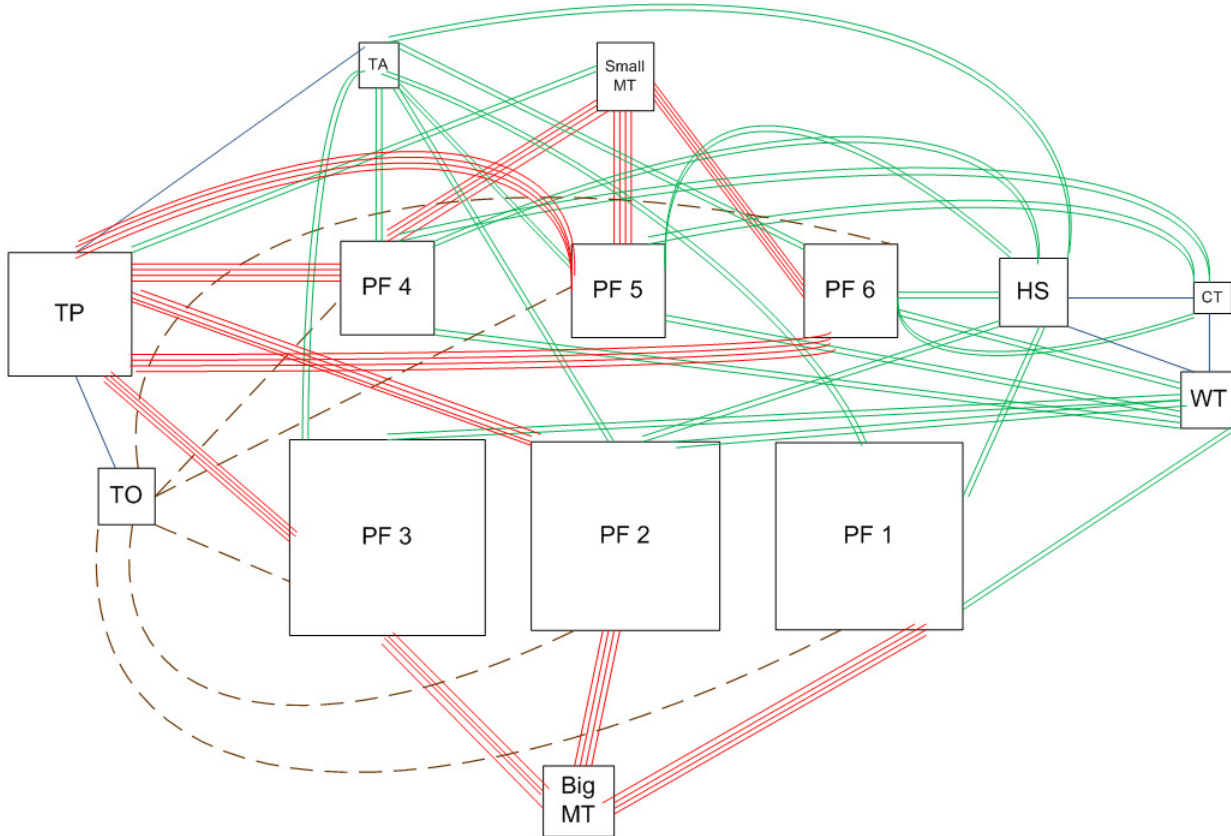
**6. Activity relationship diagram**



**List of Abbreviations:**

- **PF** – Platform
- **WT** – Winding Trolley
- **MT** – Material Trolley
- **CT** – Core Trolley
- **HS** – Harness Storage
- **TO** – Toolbox Operators
- **TP** – Toolbox Platforms
- **TA** – Toolbox Assembly

## 7. Space relationship diagram



## 8. Practical limitations

The platforms are fixed in the positions that they currently occupy. Green areas exist in the active assembly area that cannot be put to use. Areas for the workers to occupy during their tea breaks are also lost space.

The overhead cranes are used to move the assembled and/or assembly parts. The cranes can only move one part at a time, and only if there is an available platform where the parts can be moved to.

### 7.3. Tool Analysis

To simplify the layout and production area three different groups of tooling were identified:

1. *A tool list for each operator.*

Currently there are two different types of toolboxes in use and these are scattered over the area. Considering the ultimate goal of good housekeeping, universal toolboxes were decided upon. Demarcation areas on the layout will promote a neater and thus safer work environment.

BEFORE



AFTER



**Figure 11.1: Toolboxes**

The new toolbox is more compact, mobile, and easier to handle and keep neat, making inspections more efficient.

The top part can be conveniently separated from the body if needed.

Apart from finding the correct toolbox that can be utilized by each operator, the content needed to be sort out. Toolbox inspections and the analysis of the assembly process assisted with the development of an updated operator toolbox list that can be seen in appendix H.

2. *Tool list for each platform/ scaffold*

A toolbox located near each platform should contain all the tools that are needed by the platform. The tool list can be viewed under appendix H.

3. *Tool list for assembly area*

Tools utilized by the entire assembly area are listed here. It includes the overhead cranes and other more expensive tooling. See appendix H.

Correct tool usage is very important as it ensures a prolonged tool life-cycle and can minimize any possible damage to the assembly parts. The scheduling and upkeep of maintenance and inspection activities for the different tooling need to be determined beforehand. This will ensure that any occurring problems with the tooling can be identified and solved before it has a negative effect on the production output.

#### **7.4. Material Analysis**

The master production scheduler determines ahead of time which “projects” will be built in the active assembly area. This entails intricate planning of the availability of the overhead cranes, the relevant platforms to be used, allocating available operators to the “project”, and ordering the “project’s” materials from the insulation shop, to name a few. (The term “project” refers to the power transformer being built and assembled at the request from a customer.)

The main problem with the materials is that it is not readily available for use. Operators continuously move around to find the materials. This is because of a lack of planning. The Kanban pull-system is an ideal lean manufacturing technique to help create a production flow that runs continuously and smooth.

According to Masaaki Sato in “The Toyota leaders – An executive Guide” Kanban is “a system designed to minimize waste by which a labelled card is returned to the previous process to indicate which parts are required for the subsequent process.”

A conceptual explanation of how the Kanban pull-system works can be seen in appendix I.

The approach developed for the situation in the active assembly area will work as follows: *(It is important to note that this approach is only based on the Kanban pull-system and will cover the active assembly area.)*

- A section of the layout will be demarcated for specific use by the material trolleys. (Note that each “project” has material trolleys allocated to it)
- This section will be divided into 6 areas (one for each platform), also known as the “Material trolley bays”.
- The bay area is in a state of “ready for use” so that the next job can start without delay.
- The material trolleys will be temporarily stored in this area until the relevant “project” (which also refers to the platform where that “project” is scheduled to be built) sends for it.
- The material trolleys will then be moved to that relevant platform.
- As the material trolley bay opens, a labelled card on the label board will indicate which “project” or job card is scheduled to be build next. The operator must then get the material trolleys for that job from the insulation shop to fill the bay.
- A labelled card will also indicate which projects are currently in process or are complete.

In order for this approach to be successful, detailed planning and a joined collaboration is needed from an interrelated perspective. Visual aids (a label board and bright signalling cards) will enhance the effectiveness of the system. The marked spaces on the floor will indicate where the materials should be stored. Below is the conceptual design of the label board.

Big Platform 1		Big Platform 2		Big Platform 3		Small Platform 1		Small Platform 2		Small Platform 3	
Job Card 1	Red	Job Card 1	Green	Job Card 1	Green	Job Card 1	Green	Job Card 1	Red	Job Card 1	Green
Job Card 2	Green	Job Card 2	Yellow	Job Card 2	Yellow	Job Card 2	Yellow	Job Card 2	Green	Job Card 2	Yellow
Job Card 3	Yellow	Job Card 3		Job Card 3		Job Card 3		Job Card 3	Yellow	Job Card 3	
Job Card 4		Job Card 4		Job Card 4		Job Card 4		Job Card 4		Job Card 4	

**Figure 11.2: Conceptual design of the label board**

The visual board and associated labelled cards will be located near the material trolley bay area. The master scheduler will determine ahead of time which jobs are to be completed, in which order and on what platforms. There are three types of colour cards that will be used for each platform. The red card will indicate which jobs are completed. The green card indicates which jobs are currently in process, and the yellow card is the job who's material trolleys should occupy the bays.

The red card will always be followed by the green card and the green always by the yellow. This label board will help the operators and the master scheduler to keep track of the operations in the assembly area.

The job card will have a duplicate attached to it so that it can be removed by the operator that is getting the material trolleys to ensure that the correct materials are collected. It will contain basic information of the job/ project.

Job Number _____	Insulation Shop
Client _____	

Material Parts Numbers	Bay at which to store	Check if material trolley is complete	Operator

**Figure 11.3: Example of the job card**

## 7.5. Standard Process Analysis

Currently there is no procedural documentation available for reference at Powertech transformers. The development and implementation of a standard process map for the active assembly area will serve as guidance for the operators to refer to and follow. This will create an environment that has a unified goal that is pursued by everybody in the manner outlined in the procedural documentation. It will also aid in dissolving any irregularities that may arise during the production process. Another benefit from a procedural document is that it will assist in briefing and explaining the process occurring in the active assembly area to new operators or members of the company.

A practical walk-through and informative session was undertaken to understand exactly the how, what, where, when, and why of the assembly process. See appendix B for a review of the assembly process.

For the development of a process map for the active assembly area it is necessary to have an overview of the entire organization and to understand the interrelationships that exist between the assembly area and the rest of the organization. The company’s overall goals and missions must be kept in mind when figuring out where the assembly area fits into the company’s functional business structure. This will assist in understanding how the entire company is integrated and ultimately “who has an effect on whom”.

Operations analysis will assist in the study of identifying the process steps. It promotes the approach of defining the suppliers, inputs, processes, outputs and customers of each functional business activity. The simple example of the process of making photo copies is illustrated in the table below. This approach helps to identify all parties involved or affected by certain processes.

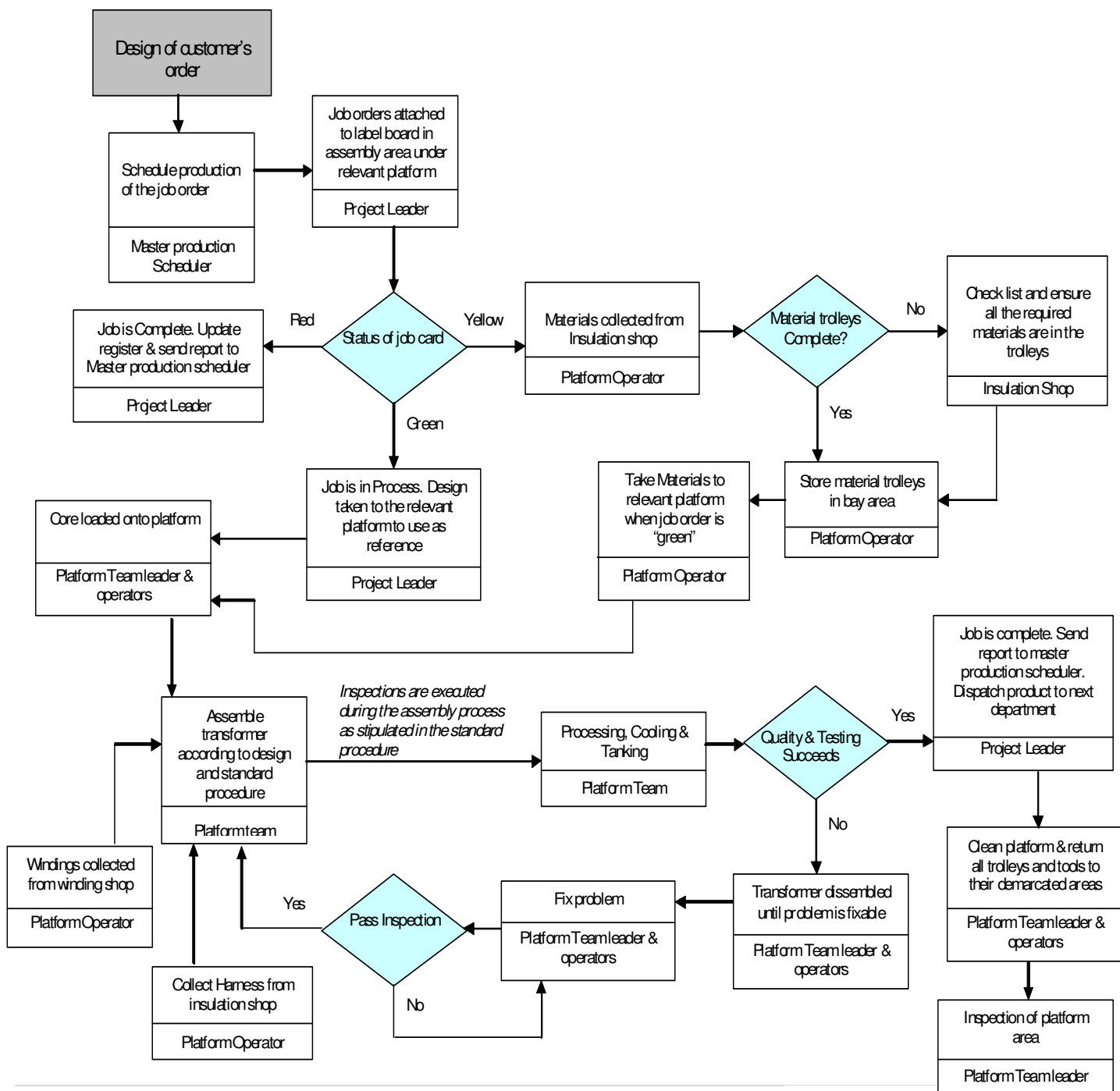
SUPPLIERS	INPUTS	PROCESSES	OUTPUTS	CUSTOMER
Manufacturer, Office supply company, Yourself, Power company	Copier, Paper, Toner, Original, Electricity	Making a photo copy	Copies	You, File, Others

**Table 2: Process evaluation procedure**

This approach will ensure a complete and thorough understanding and development of an inclusive process model.

See appendix J and K for the organization breakdown diagram and process evaluation diagram respectively.

From the process evaluation diagram and organization breakdown diagram the assembly area's process map was developed. It is depicted in the following diagram.



## 8. Conceptual Designs

The data gathered were analysed and implemented into the conceptual designs developed. See appendix L for the three alternative conceptual designs.

The differences between the three designs are as follows:

DESIGN 1	DESIGN 2	DESIGN 3
The rack for the operator's toolboxes is designed next to small platform 1.	A rack for the operator's toolboxes is designed in the entrance area (green area).	No rack for the operator's toolboxes. Areas for the toolboxes are demarcated near each platform. These areas are for the platform's operator's toolboxes.
No cleaning rack designed.	Cleaning rack designed next to small platform 1.	Cleaning rack designed next to small platform 1.
Material bins are located in green area.	Material bins are located in green area.	Material bins are located in usable area.
Harness rack located next to material trolley bays.	Harness rack located next to material trolley bays.	Harness rack located in original position.
Material trolley bay 1 (for big platform) is located next to the aisle.	Material trolley bay 1 (for big platform) is located next to the aisle.	All the material trolley bays are located next to each other.
Vacuum cleaners are next to the platforms.	Vacuum cleaners are next to the platforms.	Vacuum cleaners are on the platforms.

From the comparisons above it is easy to see that design 3 is the best option as it will cost less to implement, has made provisions for cleaning, is conveniently designed, and has more space available for easy movement.

The different areas depicted in the layout will be demarcated using tape and labelling it. This will result in improved housekeeping as cleaning equipment is provided and everything has a fixed place where it should be, keeping the layout neat and safe for the operators.

It is recommended that the operators should be giving training regarding lean manufacturing as their involvement is crucial. Powertech transformers have a training division who is in control of the planning and execution of any training incentives.

## 9. Conclusion

The current state of Powertech Transformers' assembly area is inefficient and non-profitable. This project's main aim was to optimize this area and the process by focusing on improving the following:

- The material flow
- Tool usage
- Layout of the assembly area
- Housekeeping

Operators are constantly moving around looking for the correct tools and materials, wasting time and thus leading to extra costs. Focusing on the layout of the area, there has been an attempt to rectify this situation by creating an area that promotes smooth material flow. The most appropriate methods applied to achieve this were systematic layout planning and lean manufacturing. The Kanban pull-system was used as a reference to promote continuous work flow in the area and also to help keep track of the operations in the area.

The selected conceptual design was chosen for implementation as it is less costly, promotes good housekeeping and has more free space available for movement. It has been suggested that this layout be implemented in order to reduce unnecessary waste and thereby improving the productivity of the area.

Tool analysis was done to determine the type and amount of tools needed for the assembly process. Correct tooling is of the highest importance to prevent the product from being damaged.

The process map was drawn for the area to serve as guidance for the operators to refer to and follow. This will create an environment that has a unified goal that is pursued by everybody in the same procedural manner.

This project contains suggestions on how to optimize the assembly area and offer possible solutions to some of its problems. For practical purposes it can be estimated that potential savings of around 60% can be anticipated if these plans are implemented. This is calculated by means of considering the penalty and interest costs that will be decreased as a result of improvements to the material flow, tooling, and layout.

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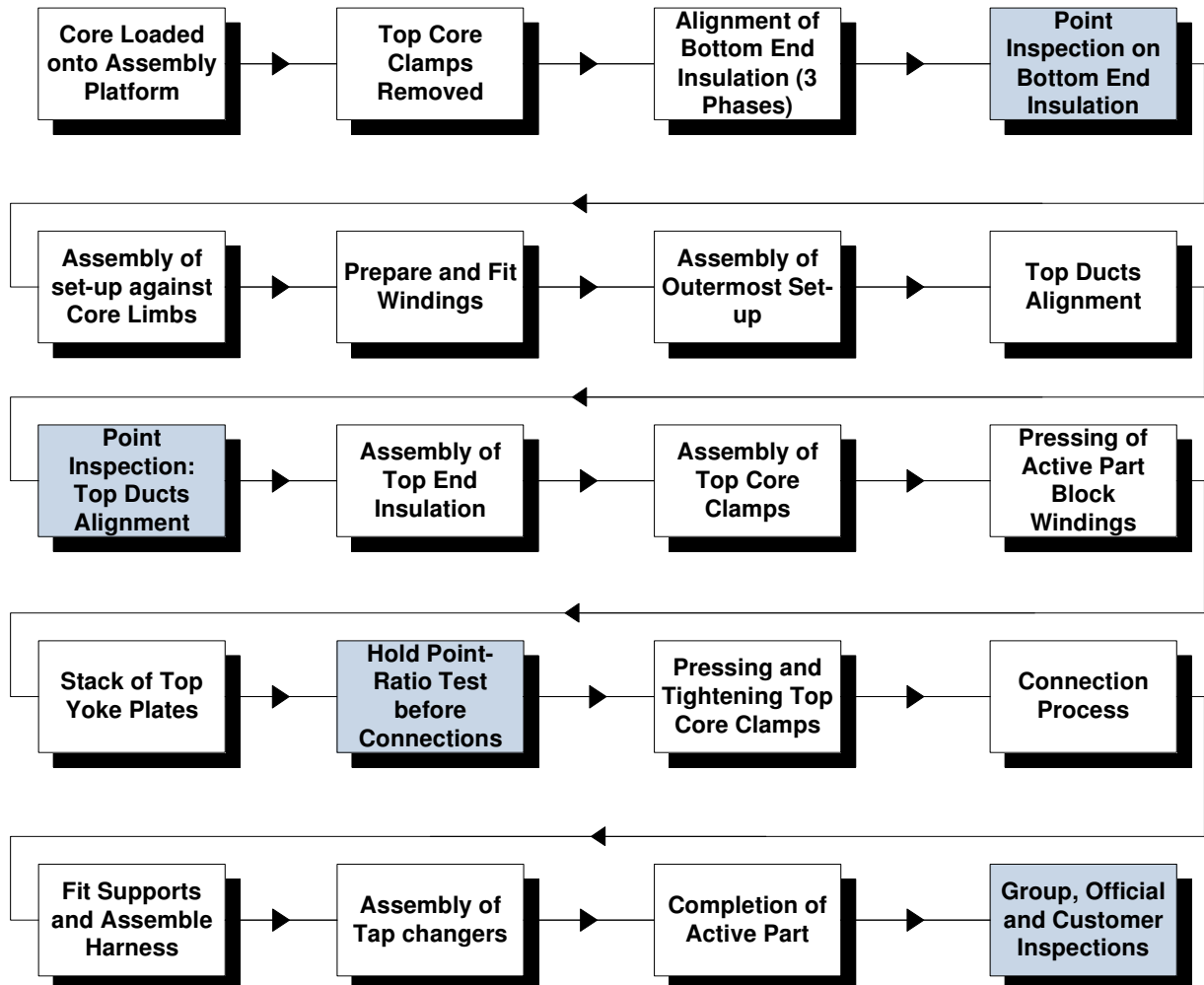
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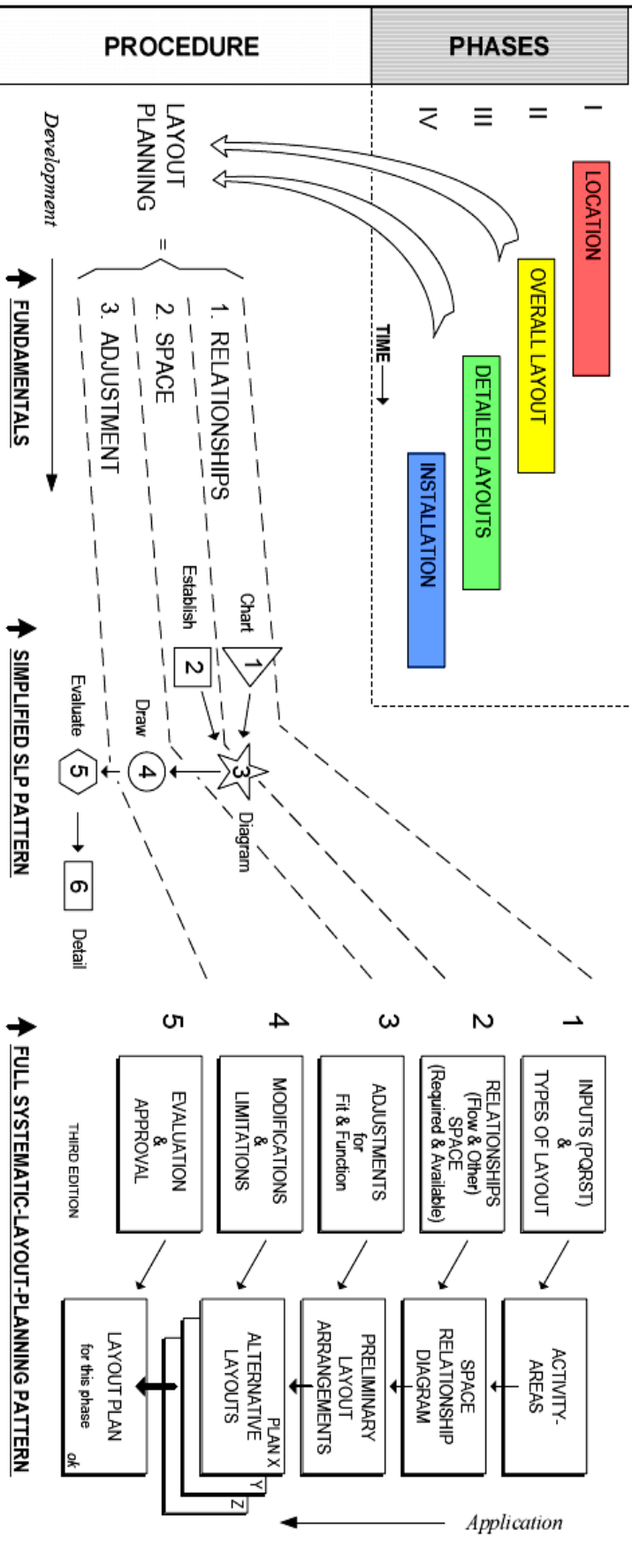
## **APPENDIX A: Layout Areas in Figure 1.1**

1. Outside View
2. Reception
3. Steel Cutting
4. Large Tank Manufacture
5. Insulation Area A
6. Insulation Area B
7. Paper Lapping
8. Core Slitting
9. Core Stacking
10. Small and Large Assembly Line A
11. Small and Large Assembly Line B
12. Large Winding Assembly A
13. Large Winding Assembly B
14. Marshalling Kiosk
15. Transformer Test Control Room
16. Transformer Test Bay
17. Transformer Despatch Area

## APPENDIX B: Activities for the Assembly of a Transformer



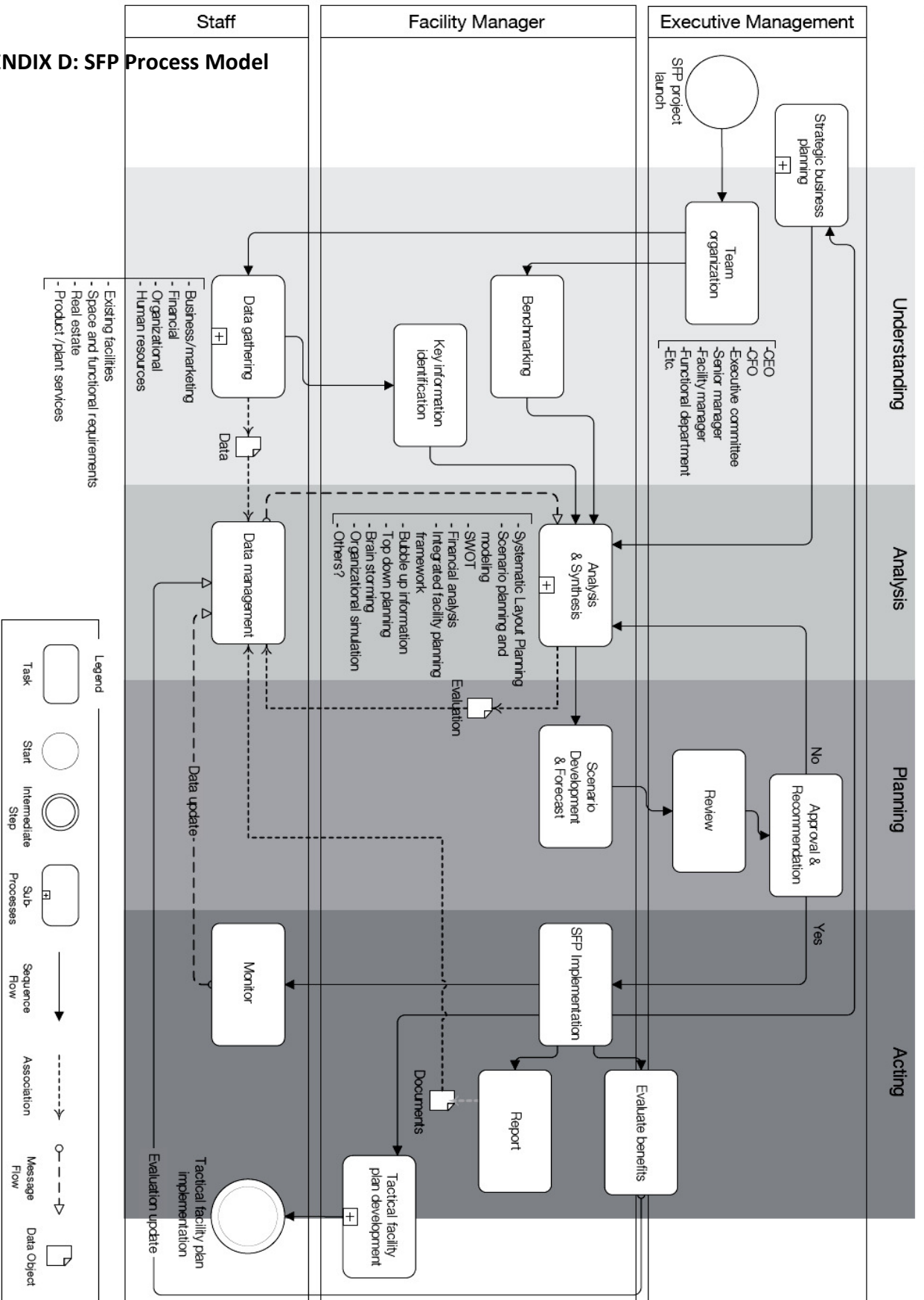
# SYSTEMATIC LAYOUT PLANNING (SLP) -- Capsule Summary



Model		Color Ident.		Importance or Intensity Rating		Evaluating Description	
○	Operation	Green**	A	Abnormally High	Almost Perfect Results (Excellent)	A/4	
○	Assembly, Sub-Assembly, Die-Assembly	Red**	E	Especially High	Especially Good Results (Very Good)	E/3	
⇨	Transport-related Equipment & Space	Orange Yellow**	I	Important	Important Results (Good)	I/2	
⇨	Handling Areas - Pick-up & Set-Down	Orange Yellow**	O	Ordinary	Ordinary Results (Fair)	O/1	
▽	Storage Equipment and Space	Orange Yellow**	U	Unimportant	Unimportant Results (Poor)	U/0	
⏸	Set-down or Hold Areas	Orange Yellow**	X	Not Desirable	Not Acceptable Results (Not Satisfactory)	X/?	
⏸	Inspect, Test, Check Equipment & Space	Blue**	XX	Extremely Undesirable		X/?	
⏸	Service & Support Equipment & Space	Blue**					
⇨	Office or Planning Areas, or Building Features	Brown** (Grey)					

APPENDIX CONVENTIONS

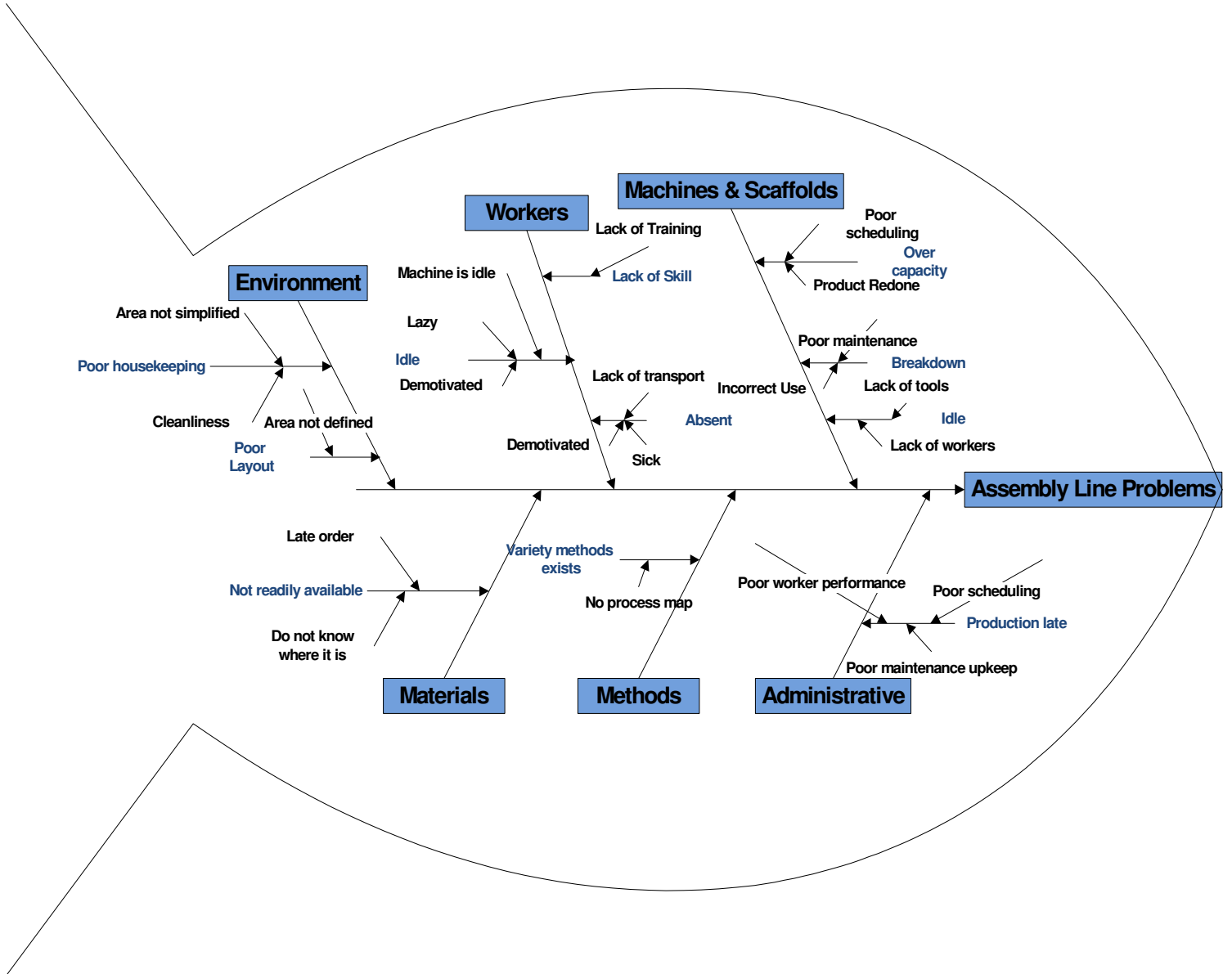
© 1989, RICHARD MUTHER © 2002, RICHARD MUTHER & ASSOCIATES RMA - 1154K



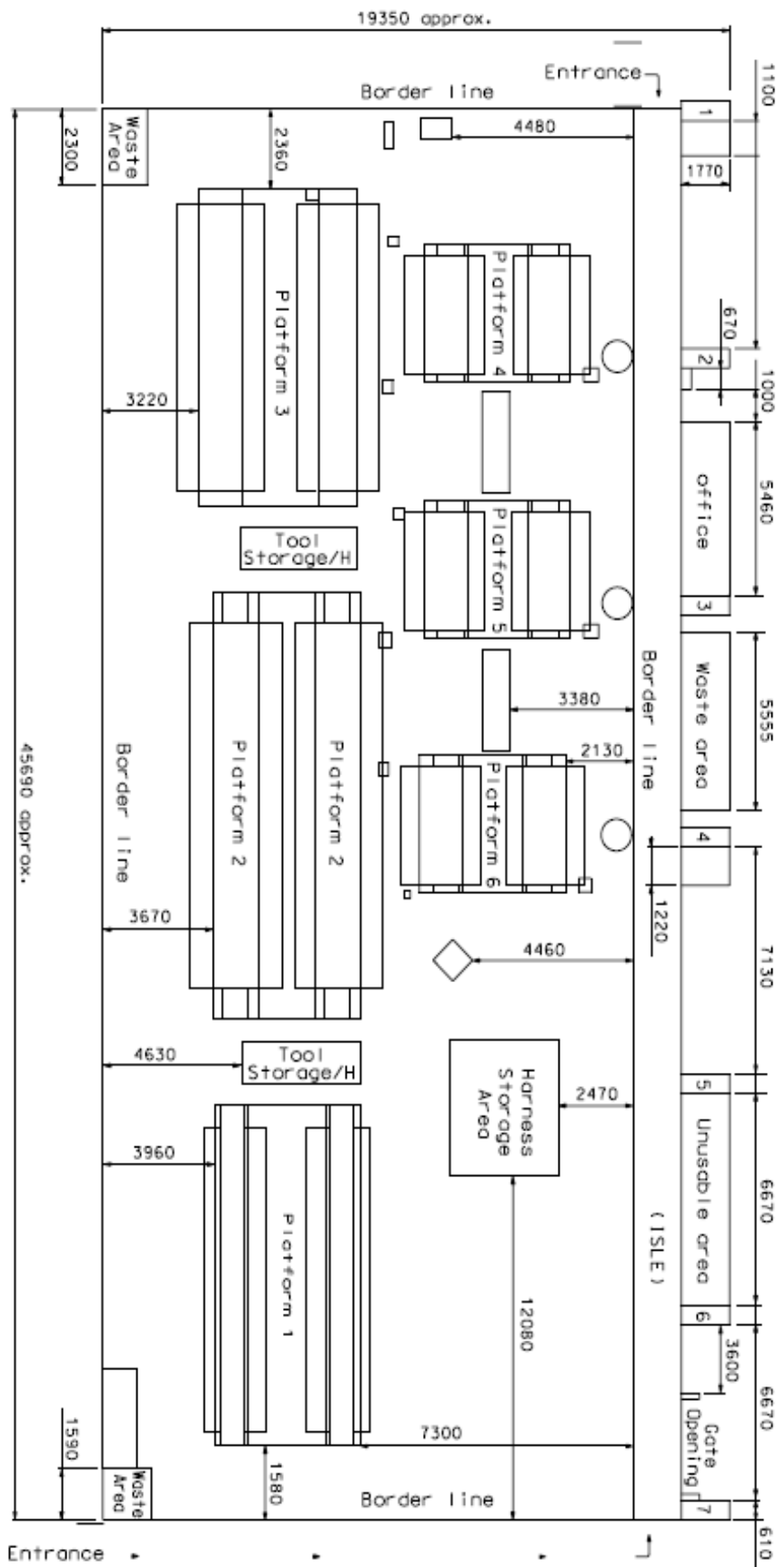
APPENDIX D: SFP Process Model

Figure 2. SFP Process Model  
Winer, Leon (2008) MBA Toolbox, Chapter 1.2, access online: [http://mbatoolbox.org/stories/storyReader\\$19](http://mbatoolbox.org/stories/storyReader$19)

APPENDIX E: Fishbone diagram



APPENDIX F: Initial layout design

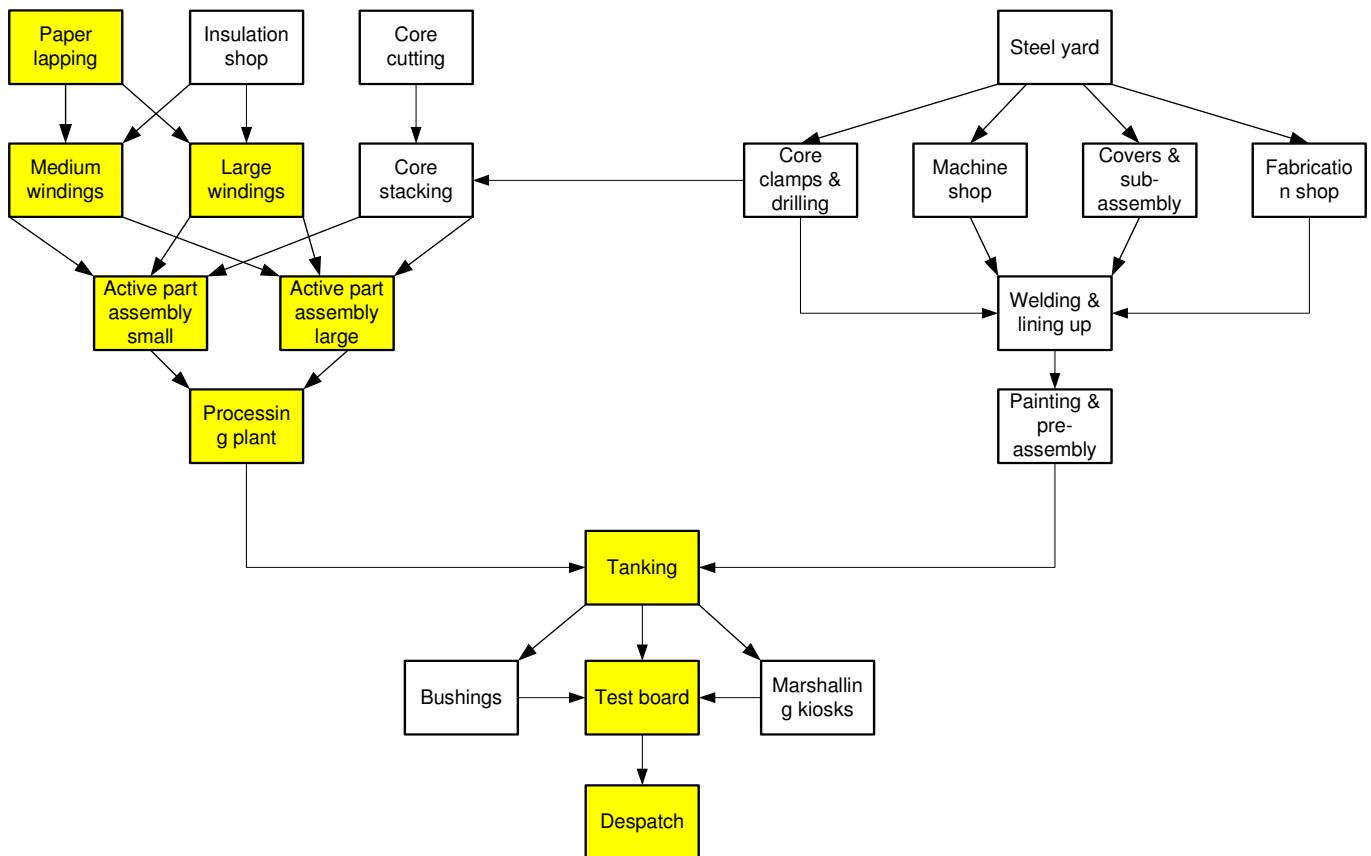


Scale 1:100



**APPENDIX G: CPM applied to the entire production process**

Path for manufacturing a transformer  
(Critical path in yellow)



**APPENDIX H: Toolbox List for operators, platforms and the assembly area**

<b>Tool List for Each Operator</b>			
<b>Tool</b>	<b>Description</b>	<b>Quantity</b>	
Combination Spanner (Flat ring)			
Sizes:	10mm	1	
	13mm	2	
	16mm	2	
	17mm	2	
	18mm	2	
	19mm	2	
	24mm	2	
	30mm	2	
Socket			
Sizes:	10mm	1	
	13mm	1	
	16mm	2	} Long & 1 Short
	17mm	2	
	18mm	2	
	19mm	2	
	24mm	2	
	30mm	2	
Allen key socket			
Sizes:	6mm	1	
	8mm	1	
	10mm	1	
	14mm	1	
Hammers	2lb	1	
	4lb	1	
Rubber Mallet	2lb	1	
Hacksaw	Large	1	
	Junior	1	
Ratchet	Long	1	
	Small	1	
Vice grip		2	
Pliers		1	
Water pliers		1	
Tin snipper		1	
Tape	5m	1	
	3m Swedish	1	
Knife	Swedish knife	1	
Allen key set	Long arm 9 pieces	1	
Torch	Mini Mag light	1	
Chisels	Med	1	

	Large	1	
Knife sharpener		1	
Pen		1	
Hand gloves		1	
Fibre Socket Size 30mm		1	
Extension Sockets for Ratchet	Long (250mm)	1	
	Short (175mm)	1	
Glue Bottles		1	

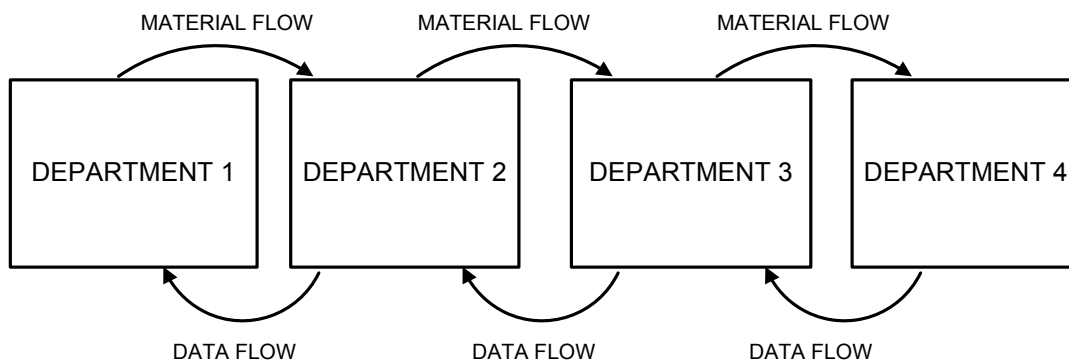
<b>Tools for each Platform</b>		
<b>Tool</b>	<b>Description</b>	<b>Quantity</b>
Vacuum cleaner		2
Cutters	Big wire cutters	2
Ratchet	Long 3/4 inch	1
Sockets	36mm long	1
	41mm long	1
	46mm long	1
Enerpack air pump		1
Measuring tape	10m tape	1
Belt	3m ratchet belt	6
	6m ratchet belt	6
Elpress machine		2
Crimping heads	Small head	2
	Large head	1
Punches	Hollow punches	1 set
Measuring equipment	Vernier	2
Flat/ring spanner	36mm	1
	41mm	1
	46mm	1
Torches	Mag light torches	2
Hammer	16lb hammer	1
Stamps	Small letter stamps	1
Levels	Spirit levels long	2
Kits	Power punch kit	1
Torque wrench	Torque wrench 40-200Nm	1
Wire stripper	Crimping heavy duty wire stripper for crimping shields lugs	1
Cable reel	Open drum cable reel (twin socket) extensions 35M	2
Dies	Trolley with crimp and pre-rounding dies	1
Fiber wedges		2
Steel wedges		4
Calculator		1
File		4
Set screwdrivers		1
Bending tool		4
Wire cutting tool		1
Stack knives	Big PF	12

	Small PF	10
Pennetjies		2

<b>Tool List for Assembly Line</b>		
<b>Tools</b>	<b>Description</b>	<b>Quantity</b>
Core cheeses stacking Jigs	Stacking jigs	3
Block	1 ton	1
	2 ton	3
Core cheeses lifting tool	Lifting tool	2
Lining up cross flux plate jigs	plate jigs	10
Flat ring Spanner	95mm	2
	55mm	2
Heat gun	For big PF	2
Ratchet	M16 200Nm	1
Ratchet belts	Belts	20
Pipe Spanners	24mm	1
	28mm	1
	32mm	1
Extractor Fan	Points	3
	pipes	2
Hydraulic G-clamp	Big	3
	Small	3
G-clamps for stacking	Big PF	12
	Small PF	4
Press bolts	200 ton	4
	100 ton	4
	60 ton	8
	50 ton	4
Stiffeners	200 ton	4
	100 ton	4
Top press beams		4
Trestles		2
Bottom press beams		8
Pulling jacks	(Big PF) 100 ton	4
	60 ton	4
	(Small PF) 60 ton	4
Hydraulic Power Pack	20 ton	1
	30 ton	2
	60 ton	2
	100 ton	1

High frequency machine		2
Grabs		1
Winding grabs	Small	3
	Big	1
Cranes	5 ton	2
	30 ton	1
	150 ton	2
Enerpak Pneumatic Power pack		4
Enerpak Hydraulic Air Jacks	(Big PF) 30 ton	4
	(Small PF) 30 ton	8
	10 ton (short)	14
	10 ton (long)	17
	15 ton	3
Enerpak hand pump		2
Shackles		4
Bushing Lining Jig		1
Tap changer jig		1
Cylinder jacks	100 ton	4
Hydraulic pressure pump	for fire hoses	1
Magnet block	for end support	1
Spacer blocks	for big jacks	10
Spreader beams		1
Hydraulic Pulling Jacks	30 ton	8
	15 ton	8
Hydraulic Gauges	15 ton	2
	30 ton	1
	60 ton	3
	100 ton	1
Nylon Slings	9m - 100 ton	2
	9m - 80 ton	2
	10m - 100 ton	2
	7.6m - 100 ton	2
	7m - 80 ton	2
	6m - 15 ton	4

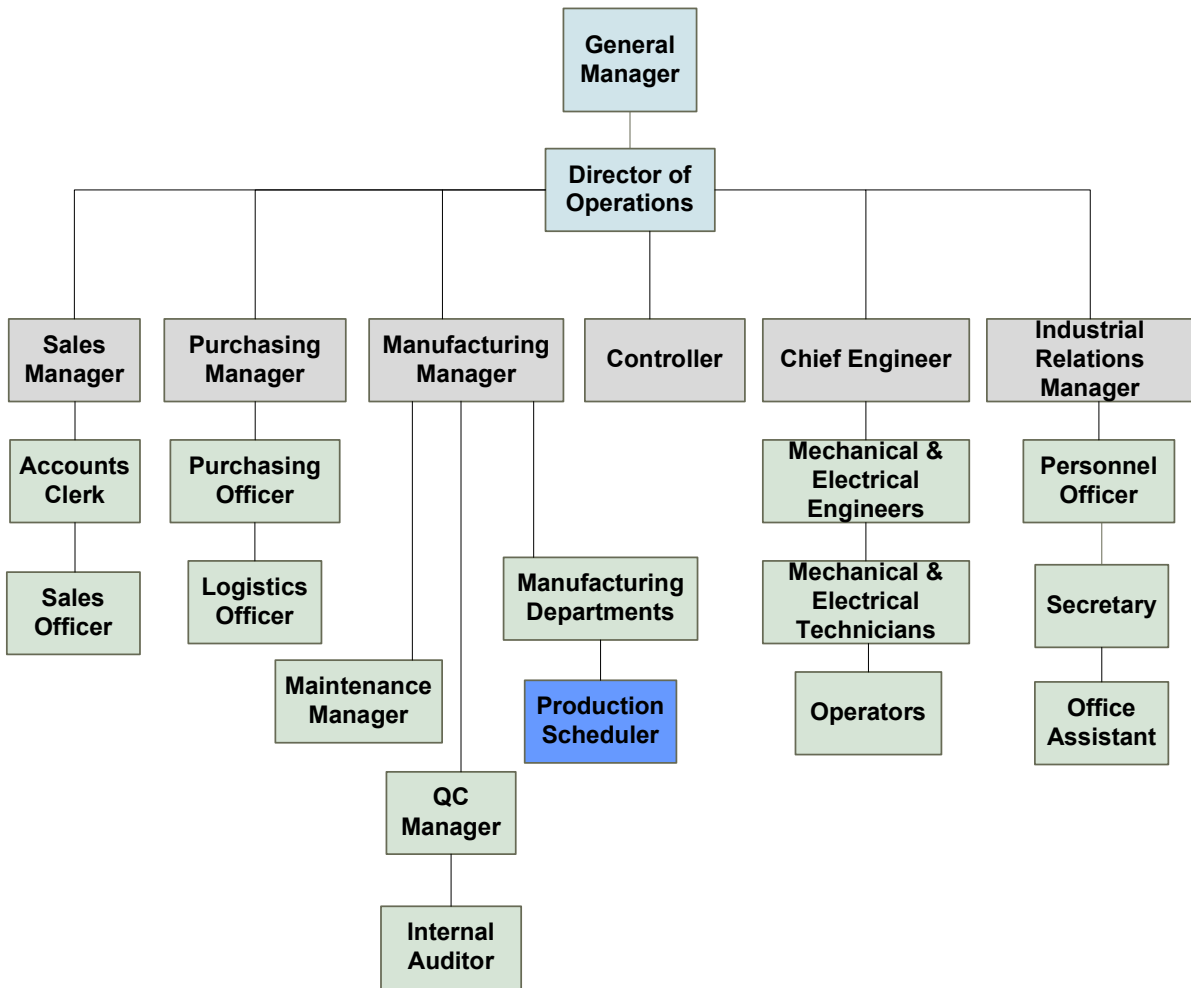
## APPENDIX I: Simplified explanation of how the Kanban pull system works



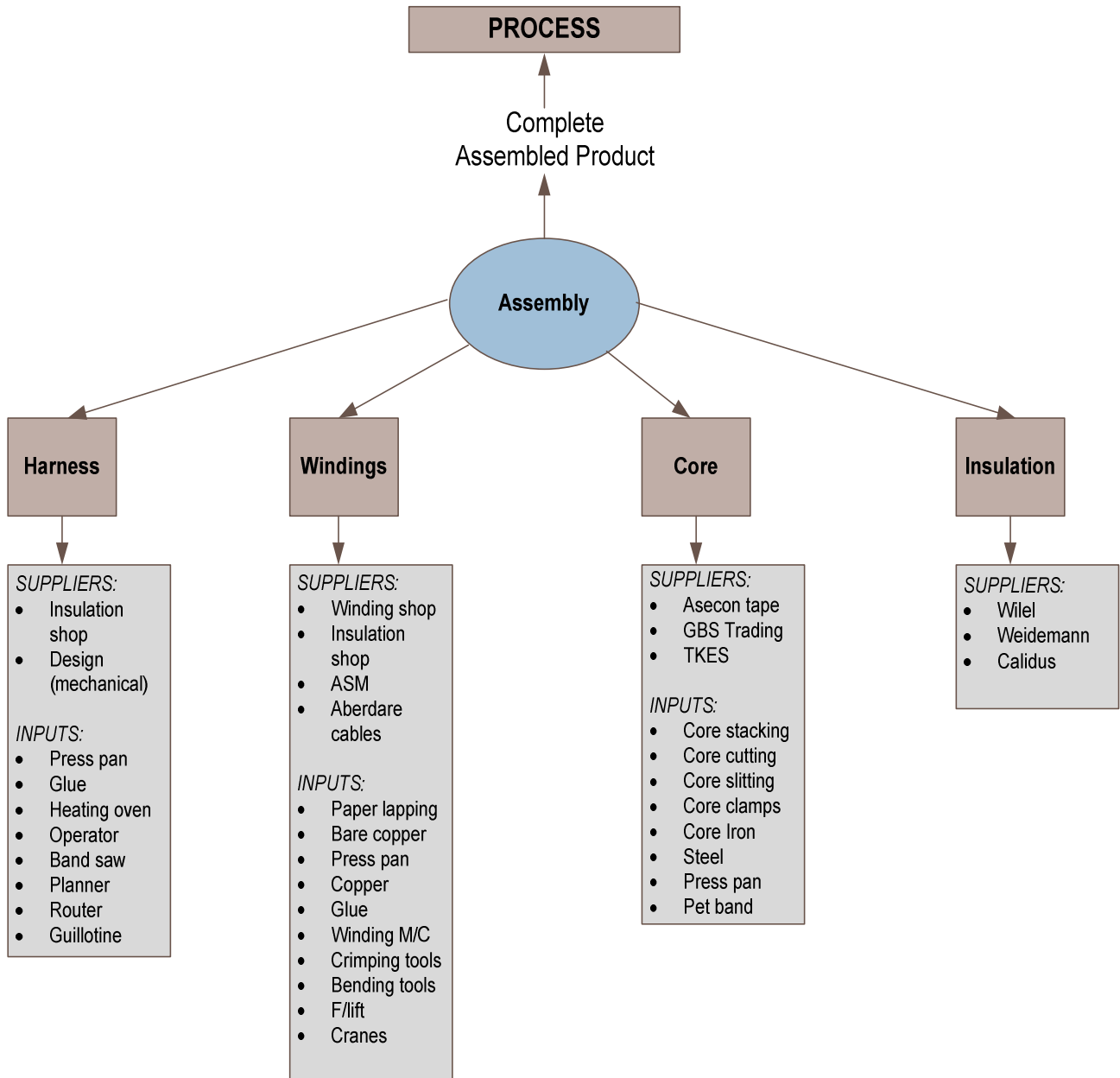
The Kanban pull system is executed by means of a labelled card that is returned to the previous station/ department to indicate which parts are required for the subsequent process, thus which parts has already been used.

The main goal of the Kanban pull system is to minimize waste by ensuring that the correct amount of materials/ parts are available when and where needed.

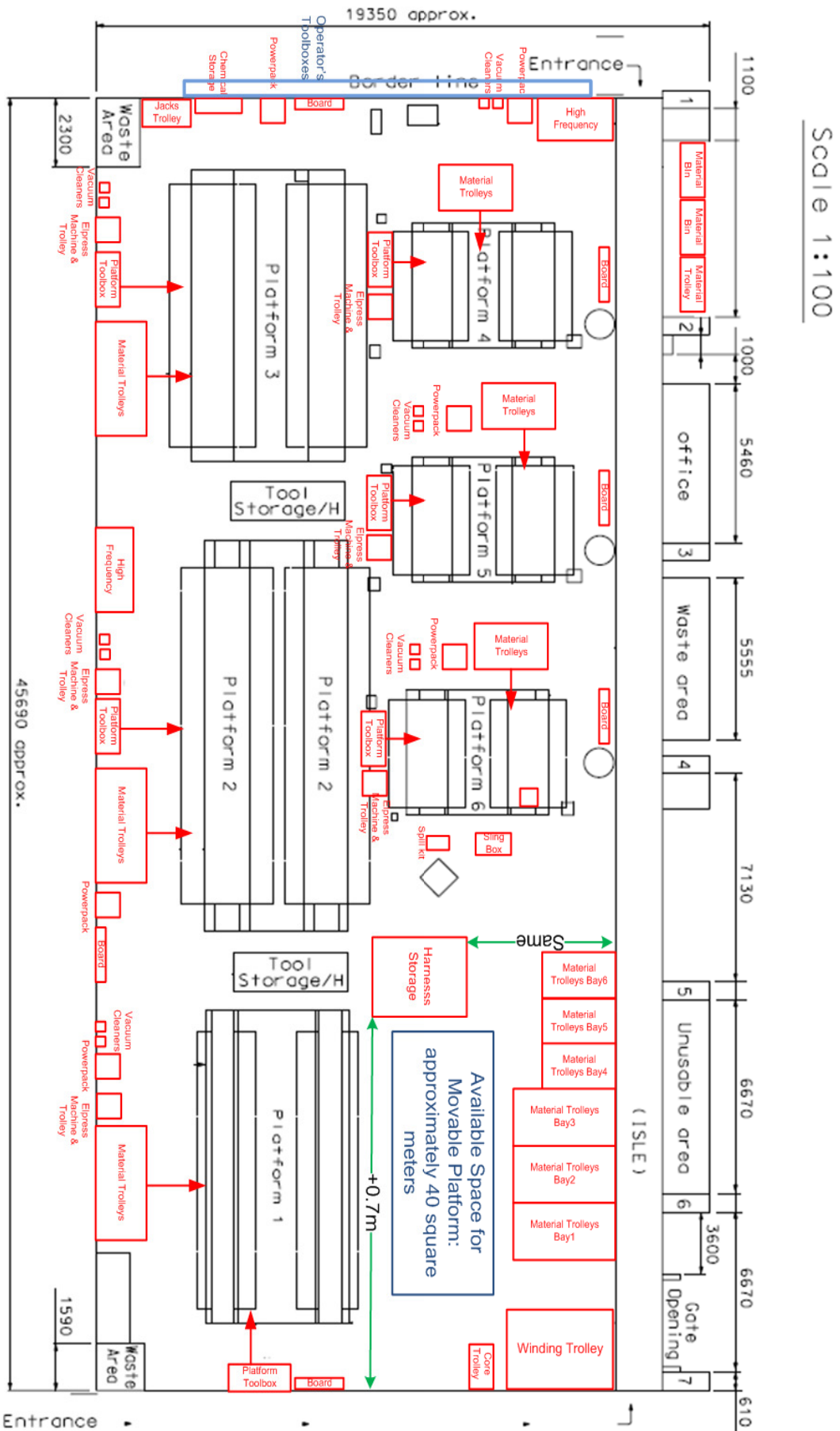
**APPENDIX J: Organization breakdown diagram**



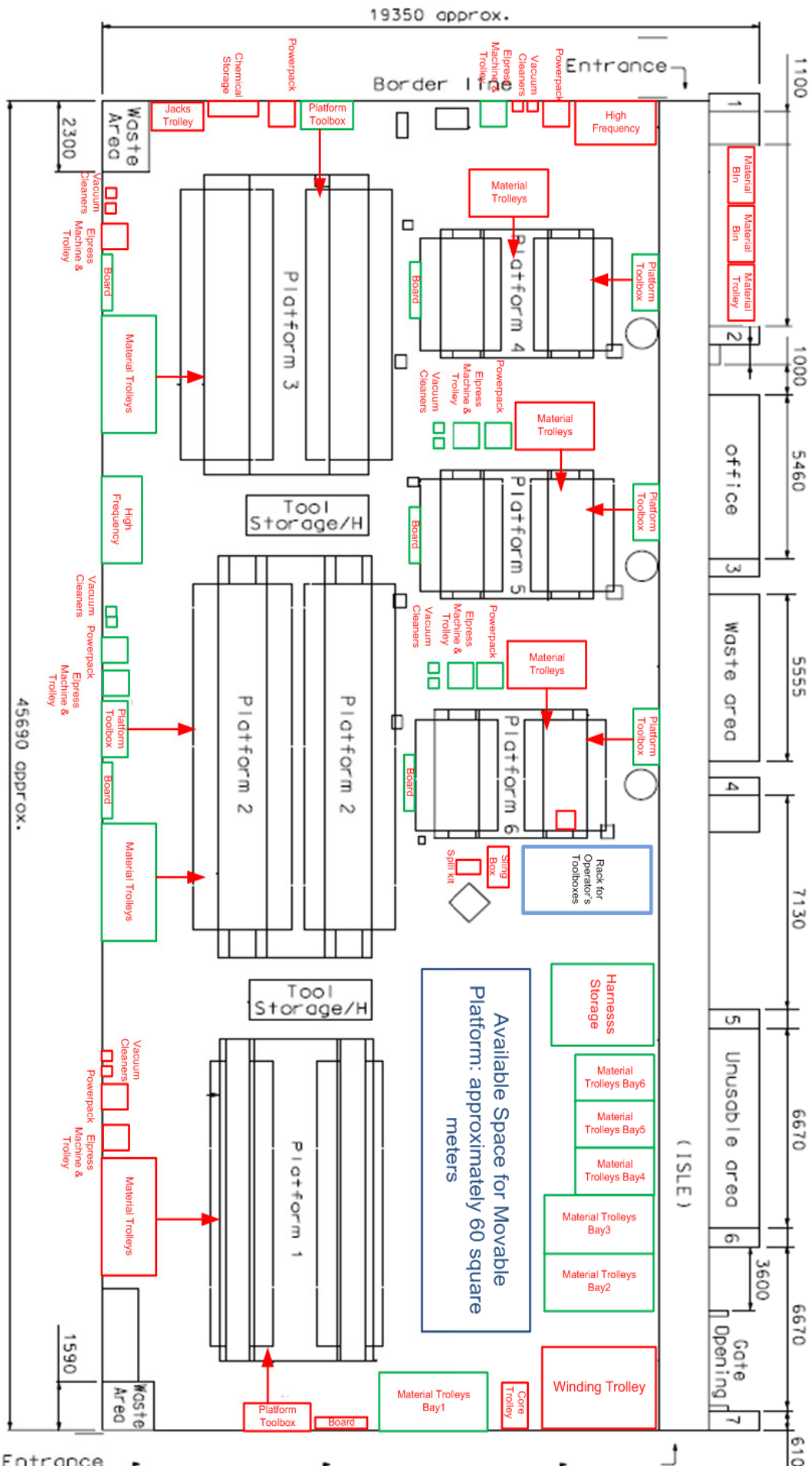
**APPENDIX K: Process evaluation diagram**



# APPENDIX L: Conceptual Design 1



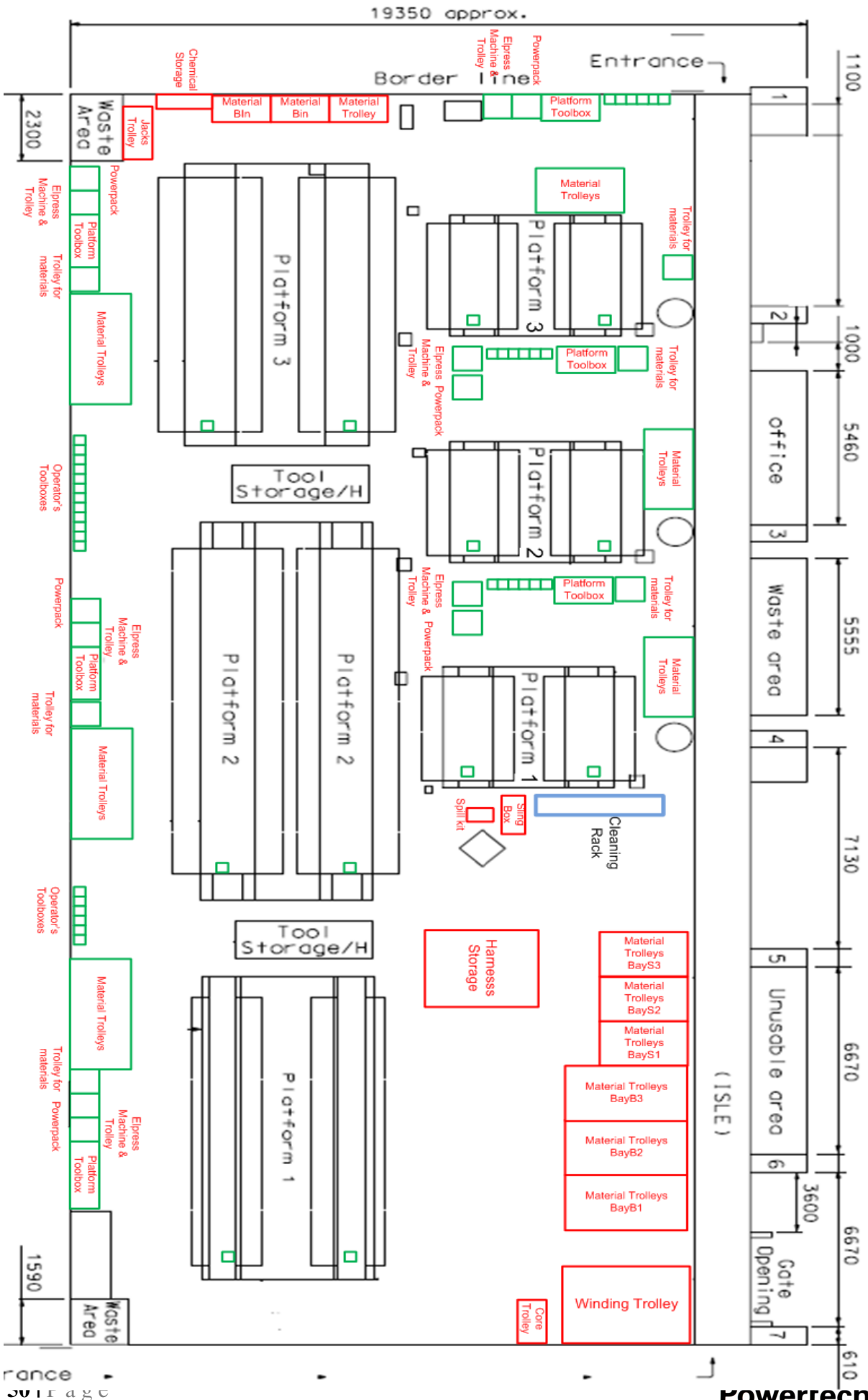
# Conceptual Design 2



Scale 1:100

Selected alternative (Conceptual Design 3)

Scale 1:100



Entrance  
Scale 1:20