

**Components Paint Facility Upgrade to Improve
Production Efficiency, Quality and Working
Conditions**

By

Willy Sizo Masombuka

04420144

**Submitted in Partial Fulfilment of the Requirements
for the Degree of**

Bachelors of Industrial Engineering

In The

**Faculty of Engineering, Build Environment and
Information Technology**

University of Pretoria

October 2011

Executive Summary

Increased market competition has placed much strain on organisations to improve quality of the service they provide. It is now every organisation's goal to continuously improve its day to day operations in order to attain efficiency in their manufacturing environment.

This project addresses production ineffectiveness as experienced by UCW Company situated at Nigel, specifically within the Components Paint Shop. The key objective of this project is to design an improved facilities plan for the Components Paint Shop, with appropriate and efficient material flow and handling system. The facility should optimise production efficiency by improving the working environment.

In execution of the project, information was gathered and analysed in order to determine best practices that will assist in developing an efficient and feasible solution. Facilities Planning techniques and tools are used to design possible solutions of the problems. Therefore, different solution designs are proposed and evaluated to select the best design that addresses the problem at hand.

Three alternative layout configurations are proposed and evaluated based on design criteria set for the painting facility. Upon evaluation, Alternative layout 3 is selected as the best alternative. The selected layout optimise production efficiency, ensure minimum compliance to minimum requirements of health and safety and it also provide good working environment. New workstations have been proposed to form part of the production process in the Components Paint Shop. It is proposed that a conveyor system be used to handle small components during processing. This is achieved by hanging small components on trolleys with hooks and the trolleys will be hooked and moved with a chain conveyor through workstations.

Implementation of the proposed solution required high capital expenditure. An estimated cost of R5 818 268 will be required to implement the proposed solution. It is however recommended that the company invest capital to improve and upgrade Components paint Shop facility.

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Chapter 1: Overview

1.1. Background

Facilities planning are one of the most critical activities to be systematically performed to ensure an effective and efficient manufacturing and production system. The facility layout of any organization has an impact directly or indirectly on the rate of production, production costs and the work flow. With increased market competition in delivering quality service, organizations attempt to employ continuous improvement in order to attain efficiency in their manufacturing environment. Hence, facilities planning became the foundation to achieve the organizations goals.

Union Carriage and Wagon (UCW) was founded in 1957. It was established as a joint venture between Commonwealth Engineering of Australia and the Budd Company of the USA and Leyland, with operations based on a 37 hectare facility at Nigel, South Africa. The company specializes in designing and manufacturing of electric locomotives, diesel electric/diesel hydraulic locomotives, intercity passenger coaches, electric multiple units, railcars and all-purpose freight wagons. The other service the company offers is refurbishment and upgrading of rolling stock.

Since 1957 the company has designed and manufactured 14 000 locomotives, suburban trains and coaches. UCW has engaged and served local, regional and selected export markets. Local customers that the company has served include MARS (Mitsui & African Railway Solution), Passenger Rail Agency of South Africa (PRASA), Transnet Freight Rail and VENUS Railway Solution. The company has also exported their products internationally to clients such as Angola Railways, Botswana Railways, Malawi Railways, Malaysia (KTMB), Taiwan Railway Administration and Zimbabwe Railways.

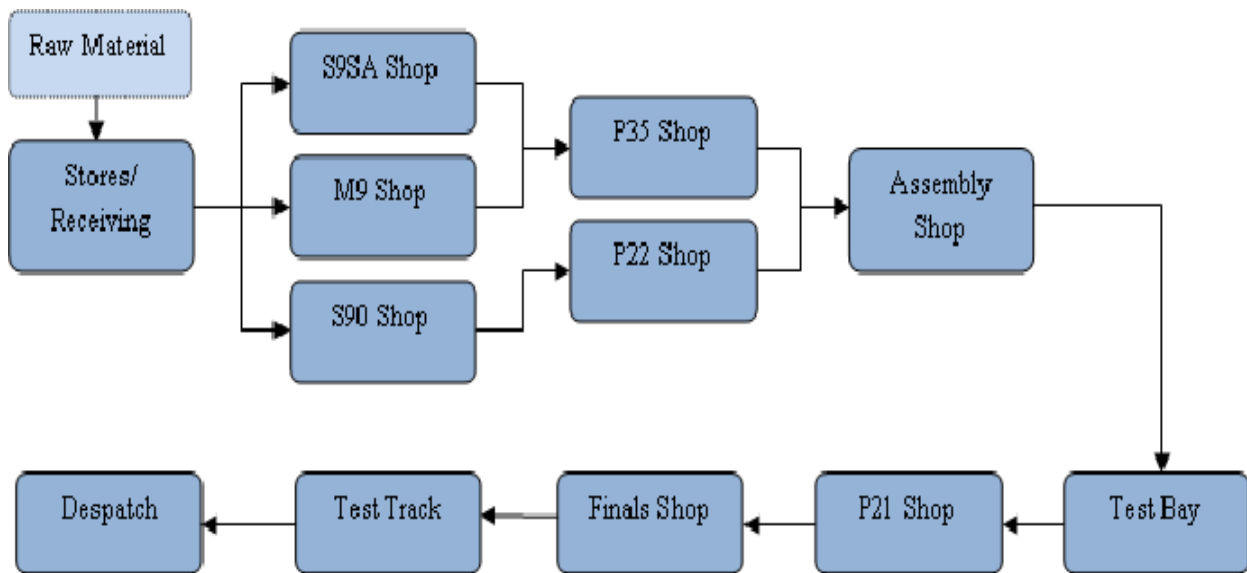
The 37 hectare plant is divided into departments and further into shops. Key departments within the plant are:

- Assembly lines

- Gautrain assembling
- Test track
- Components fabrication
- Paint shop
- Maintenance
- Planning
- Engineering and design
- Purchasing
- Health care
- Receiving, despatch and stores
- Finals

There process flow of UCW is illustrated on the Figure below.

Figure 1: UCW Process Flow Diagram

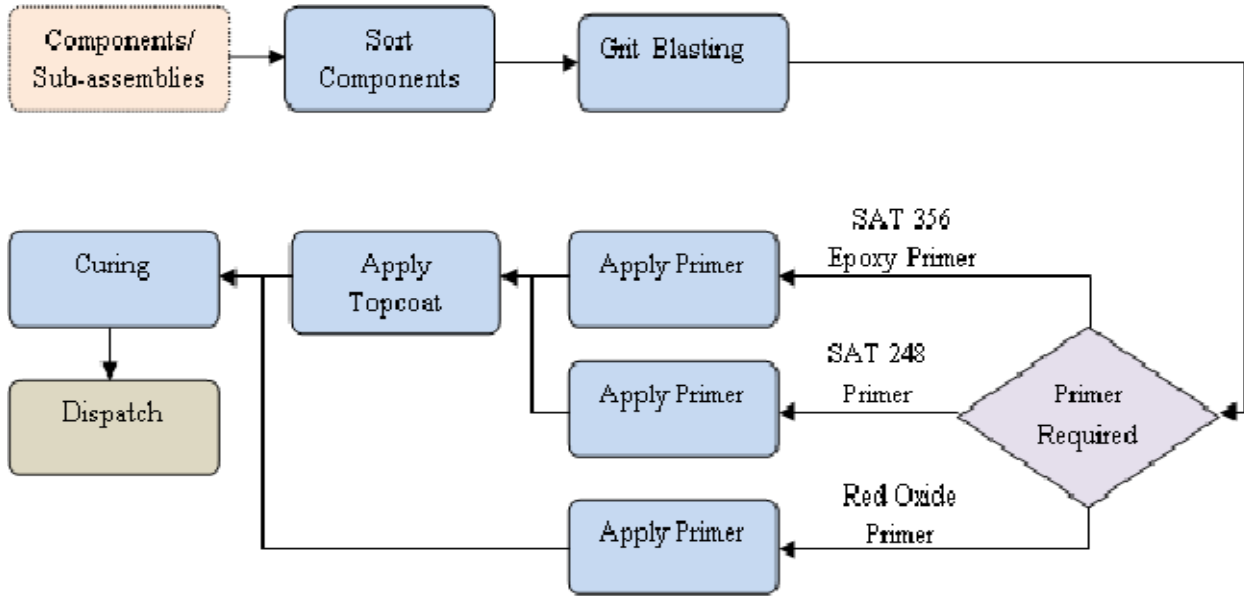


As illustrated in Figure 1 above, deliveries of raw material are made at stores. Raw material is then taken to fabrication shops (S9SA, M9 and S90) on requisition. After fabrication, big fabricated components/sub-assemblies e.g. underframes, bodysides, roofs and front and rear wall partitions are dispatched to P22 paint shop for undercoating. Small sub-assemblies and fabricated components are dispatched to the Component Paint Shop 35 (P35) for coating. The coated units and components are then taken to assembly shop for assembling. The assembled units e.g. locomotives, are then sent to test bay for water testing, electrical testing and slewing. The units after being tested, are submitted to Paint Shop 21 (P21) for final top coating, then to finals to mount or insert sits and do touch ups. Before the finished locomotives are dispatched to customers, they are tested on UCW designated railway with power lines called test track.

The current projects of the company are; the manufacturing of 19E Locomotives for Venus (Transnet Freight Rail), 15E locomotives for MARS (Transnet Freight Rail), assembling of the Gautrain passenger trains, and upgrading of 10M4 S2 EMU and 5M2A passenger trains for Passenger Rail Agency of South Africa (PRASA).

The Components Paint Shop 35 (P35) is responsible for the coating of fabricated components and smaller sub-assemblies for the assembly of locomotives. There are two types of painting done at P35. One is an undercoat or primer and the other is final topcoat. The coating applied is used as protection for the material against corrosion during handling, movement and further processing and for aesthetic or appearance of the components. The P35 facility runs on a 5 day production cycle in which it processes 1100 components for 19E and 1200 for the 15E locomotives. The processing of components in P35 is illustrated in Figure 2 below.

Figure 2: P35 Process Flow Diagram



Components arrive at P35 and are then sorted according to their shapes, sizes and processing sequence. After sorting, the components are cleaned by means of a grit blasting process. There are three grit blasting stations in P35 facility. Flat and straight components go through a rotating nickel plating machine; sub-assemblies and other bigger fabricated component have their designated grit blasting booth and another dedicated to small components, called wheel-abrator. The components are then coated after the cleaning process. Some components are only coated with red oxide primer.

Components coated with red oxide primer are dispatched to welding or structure shop to be welded and form subassemblies, e.g. ducting, deckplate and side sill will be put together to form an underframe. Red oxide primer is used because it can be welded with ease and protects the parts against corrosion prior to welding.

1.2. Problem Statement

1.2.1. Spray Booths

Currently, Components Paint Shop 35 has no functional spray booths. The spray booth available has outlived its working life and maintenance cannot restore its effective operability. The painting work is currently carried out under cover, open space and inside an old welding school. The conditions are harsh in terms of exposure to weather and adversely affect the quality of the final products. These unfavourable working conditions also negatively affect workers performance and result in low productivity. The pictures below depict the working environment as discussed.

Figure 3: Shaded Area for Final Coating Figure 4: Open Space for Red Oxide Coating



Figure 5: Old Spray Booth

Figure 6: Old Welding School



Spray painting performed in an open area is environmentally unfriendly. All the paint dust and fumes are not filtered or controlled and volatile organic compounds (VOCs) flow into the atmosphere. These impose health hazard to the workers and nearby community. Thus, the current facility does not comply with nor it is designed for minimum health and safety requirements.

1.2.2. Material Handling

Material at Components Paint Shop 35 facility (P35) is primarily handled by a forklift. A single forklift at P35 is used to handle bigger components between workstations, but only outside the facility. Small components are packed into crates and pallets then a forklift is used to deliver the material into the facility at receiving/sorting section. Inside the facility, small trolleys are used to move material between workstations. The trolleys are manually operated, with workers pulling or pushing them. These trolleys are also used to handle some material during coating, which minimize their availability for handling between stations.

1.2.3. Material Flow

Parts from other supply shops are delivered at the sorting or receiving area inside P35 facility. These parts are not marked to trace the parts processing sequence and get mixed. The parts are then sorted according to the production order which is attached to the batch of materials delivered. Regardless of which materials arrived first, the materials are then further sorted according to the shapes and sizes. Materials delivered first often end up not being processed on time because there is no prioritisation (e.g. first in first out principle).

Therefore, some materials end up not being delivered on time to the next processing plant. Quality of late processed materials are compromised because some of the processes are omitted when finished components are required urgently and expedited through the paint process.

1.2.4. Curing

After coating, the coated material should be allowed to dry properly according to the product data sheets specifications of the coating used. Ovens or spray booths equipped with heaters are normally utilized to cure or dry the material for a certain duration. At P35, there is one oven which is also obsolete and no spray booths equipped with heaters. Therefore, after coating, the product is left to dry at the workstation which means other parts cannot be processed until the previously processed parts are cured. This results in inefficient use of the current workstations. Sometimes the products are moved outside into the sun with trolleys used during coating, depending on the weather conditions, to speed up the curing process.

The inefficient Components Paint Shop 35 facility has drawn management attention since it directly affects the effectiveness of production and the quality of the products. It was agreed by management that the current facility need to be improved to escalate productivity and eliminate defective products.

1.3. Project Aim

The key objective of the project is to design an improved facilities plan for P35 shop, with appropriate and efficient material flow and handling system. The facility to be designed will optimise production efficiency throughout the Components Paint Shop (P35), improve the working conditions and ensure minimum compliance with the health and safety requirements for the painting environment, thus mitigating the health risk imposed on workers.

1.4. Project Approach

1.4.1. Analyse current facility and operations

A detailed analysis of the current facility and operations will be done. This forms part of the critical section that need to be done to better understand the problem on hand. In analysing the current facility layout and workflow, much emphasis will be placed on the following:

- Orientation of the current layout facility and workstations arrangement
- Material and product flow throughout the facility
- Material handling mechanism utilized
- Current processes and equipment
- Material control

1.4.2. Identify gaps and improvement required

After a thorough analysis of current operations and facilities, available gaps will be identified. The identified gaps will form the base in developing an improved facility plan and efficient material handling system through the facility. Improvements to be made must ensure that all the

current problems are addressed and facilitate effective and efficient production at the Components Paint Shop (P35).

1.4.3. Determine best practices

As part of this project, a thorough literature and industry survey will be conducted to explore best methods, tools and techniques to solve the problem at hand. This will be accomplished by making industry visits, discussion with paint, spray booths and handling equipment suppliers and conducting research based on painting standards and environments.

1.4.4. Establish design criteria

The facilities design plan to be proposed shall ensure that minimum health and safety requirements are met. The design should ensure that potential hazards imposed to workers during and after production are mitigated. Flexibility should be considered as part of the new design and more factors to be identified.

1.4.5. Develop proposals

An improved facilities layout and appropriate materials handling system will be designed and proposed. This improved facility layout design should optimise the production operations conducted at component paint shop (P35). In designing the facility layout, aspects such as workflow, material handling and loading of material during processing will be considered.

1.4.6. Evaluate proposals

Developed proposals will be evaluated and compared. The proposals will be evaluated against the identified design criteria. A recommendation will be made as to which proposal is the best.

1.4.7. Implementation plan

A plan on how to implement the solution will be drafted and proposed. The plan will account for the all necessary costs that will be accumulated and the projected time needed to successfully implement the solution. During implementation of the solution, the impact on production will be considered and accounted for.

1.4.8. Presentation

After the validation of the proposed solution, the final solution will be presented to all parties involved.

1.5. Deliverables

In completion of the project, the following will be delivered against the key project activities:

Table 1: Key Deliverables

Activity	Deliverables
1. Analyse current facility and operations	Material control and workflow
2. Identify gaps and improvement required	Facility improvement plan
3. Determine best practices	Best practice to solve addressed problem
4. Establish design criteria	Best design criterions
5. Develop proposals	Alternative proposals
6. Evaluate proposals	Best proposals
7. Feasibility analysis	Recommendations
8. Implementation plan	Implementation plan and costs
9. Presentation	Solution and report

Chapter 2: Best Practice Analysis

Information gathering in this project will assist in exploring and understanding available best practices that can be used to solve the problem at hand. This will help to develop and formulate feasible solutions for the upgrade. Different sources are consulted and utilized in conducting the literature survey. Information gathered is then analysed to select the best techniques, tools and/or methods that can be used to solve the problem, and to identify best practices.

2.1. Facilities Planning

2.1.1. Background

Literature studies have been conducted in the past on the design of facility layouts and material handling system. Tompkins and White (1984) emphasized the integration of flow paths to the design of the facility layout and material handling system. It is further highlighted that effective planning of flow paths will maximize material flow while attempting to minimize congestions on the flow paths which might result in damaged, misplaced and lost parts (Tompkins and White,1984).

Effective facilities layout planning helps in attaining an improved level of productivity through efficient material handling, flow planning, and effective workstations arrangement to minimize travel/handling distances. According to Tompkins et al. (1996), “an estimation of between 20% and 50% of operating expenses in manufacturing can be attributed to facility planning and material handling.

Inadequate planning of facilities, material handling mechanisms and flow paths constrains the organisational goals and objectives to demonstrate its competitiveness in service delivery. Such inadequate planning will result in inefficient operations and utilization of the organization resources. In the literature study conducted, some of the tools utilized to solve the facility layout related problems are presented below:

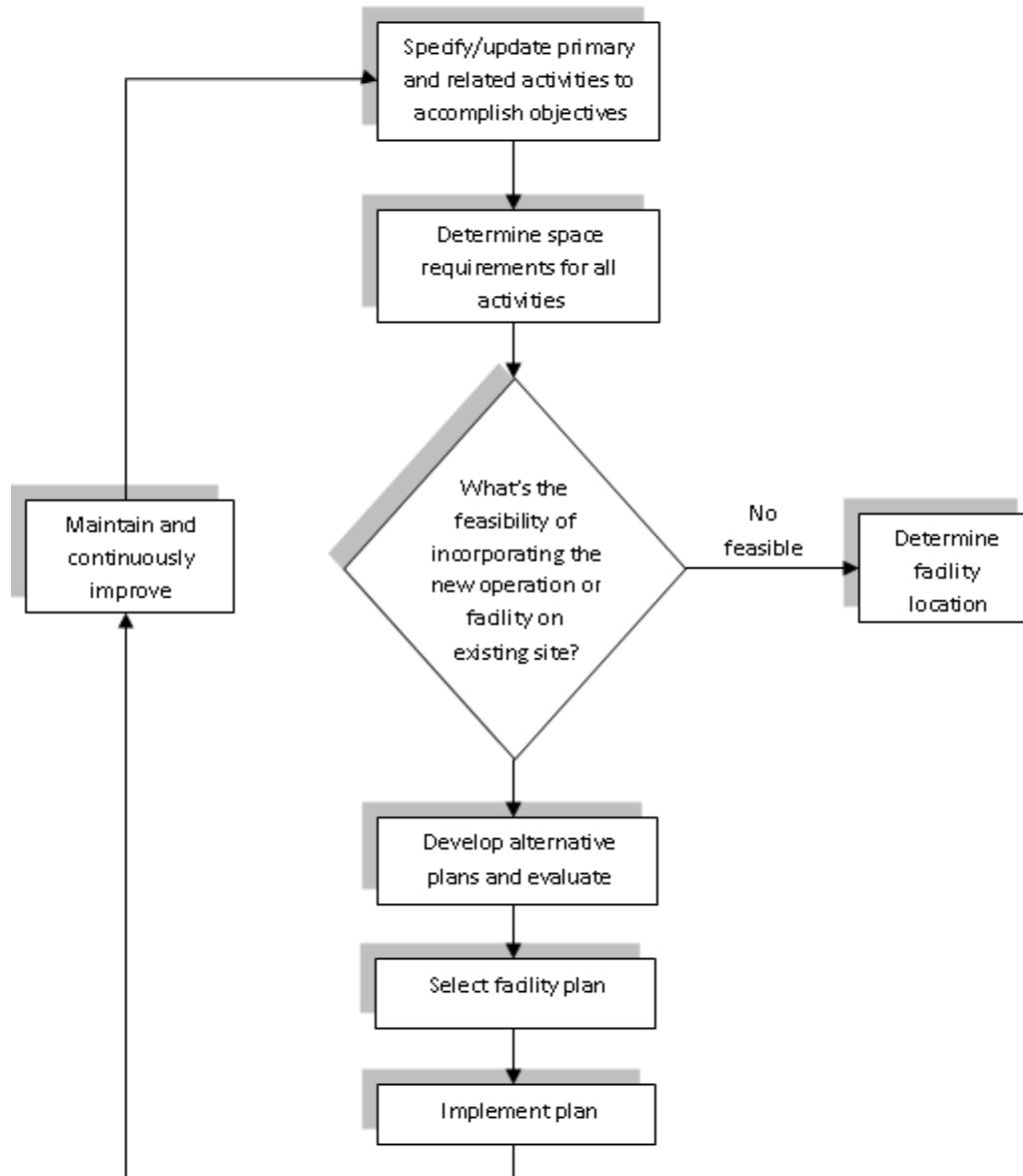
- Facility Layout Problem - Mathematical Model and Heuristics
- Facility Design and Workstations arrangement – Facilities Planning Techniques

- Work Flow Problems – Quadratic Assignment Problem Formulation
- Design Of material Flow Patterns – Loop Based Facility Planning
- Process Routing and Material handling – Mathematical Model and Facility Planning

2.1.2. Facilities Planning Process

For effective planning and design of a facility, a continuous improvement facility life cycle must be determined. The facilities planning life cycle improves understanding in facilities planning process and it enhances continuous improvement of the facility to satisfy its changing processes and objectives. Tompkins et al (2010) described a continuous improvement facilities planning cycle as follows.

Figure 7: Facilities Planning Life Cycle



This continuous improvement facility layout planning should be linked with the facilities planning process.

2.1.3. Layout Design Procedure

Given different facilities requirements and objectives, there exist different approaches of designing effective layouts. Tompkins et al (2010) documents the following list of layout procedures.

2.1.3.1. Apple's Plant Layout Procedure

The following layout procedures are proposed by Apple;

1. Procure the basic data.
2. Analyse the basic data.
3. Design the productive process.
4. Plan the material flow pattern.
5. Consider the general material handling plan.
6. Calculate equipment requirements.
7. Plan individual workstations.
8. Select specific material handling equipment.
9. Coordinate groups of related operations.
10. Design activity interrelationships.
11. Determine storage requirements.
12. Plan service and auxiliary activities.
13. Determine space requirements.
14. Allocate activities to total space.
15. Consider building types.
16. Construct master layout.
17. Evaluate, adjust, and check the layout with the appropriate persons.
18. Obtain approval.
19. Install the layout.
20. Follow up on implementation of the layout.

Apple noted that these steps are not necessarily performed in the sequence given since it is believed that no two layout design projects are the same, neither the procedures for designing them (Tompkins et al, 2010).

2.1.3.2. Reed's Plant Layout Procedure

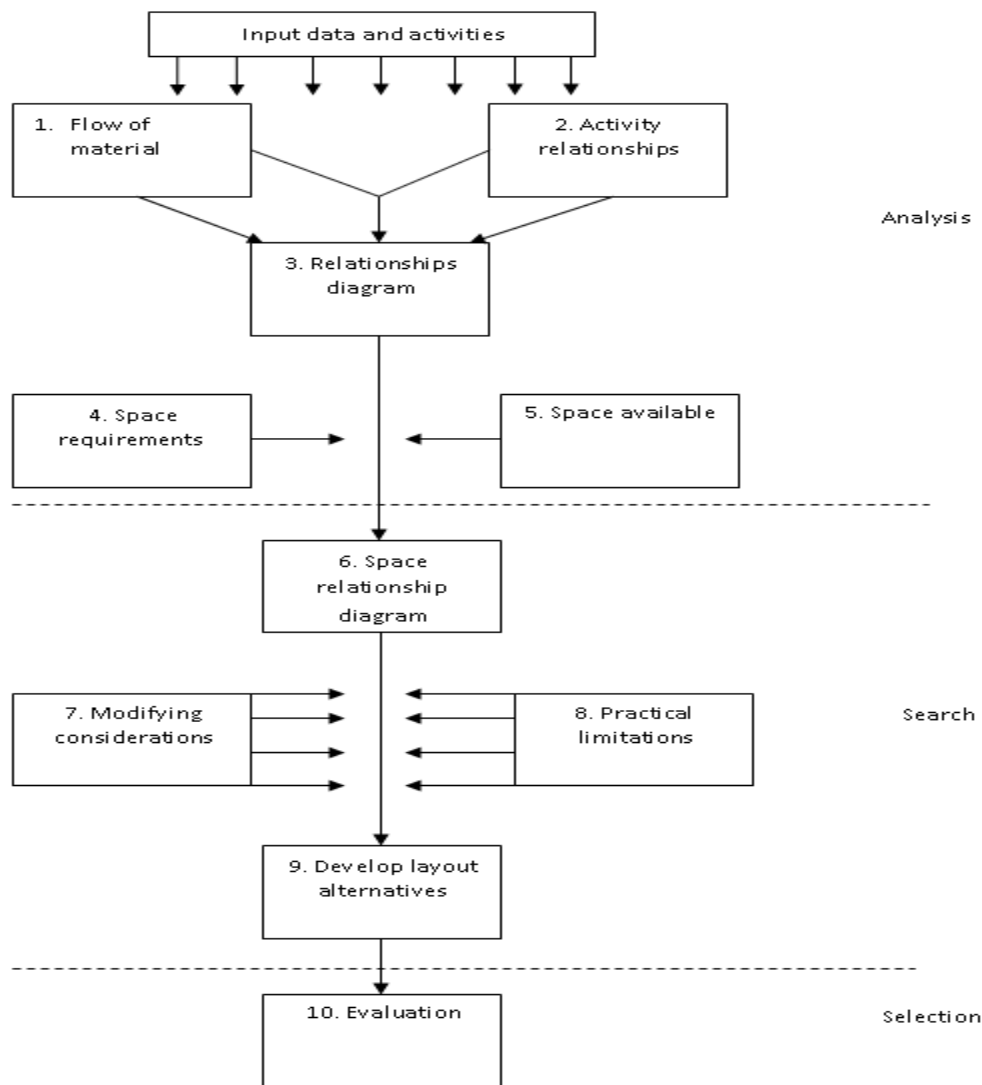
The following procedure is recommended by Reed's as required steps in planning for and preparing the layout.

1. Analyse the product or products to be produced.
2. Determine the process required to manufacture the product.
3. Prepare layout planning charts.
4. Determine workstations.
5. Analyse storage area requirements.
6. Establish minimum aisle widths.
7. Establish office requirements.
8. Consider personnel facilities and services.
9. Survey plant services.
10. Provide for further expansion.

2.1.3.3. Muther's Systematic Layout Planning Procedure

Muther developed a procedure he named systematic layout planning (SLP). "It uses the activity relationship chart as its foundation. Based on the data and understanding of the roles and relationships between activities, a material flow analysis (from-to chart) and an activity relationship analysis are performed" (Tompkins et al, 2010). The following figure describes the systematic layout planning process (Tompkins et al, 2010).

Figure 8: SLP Procedure



2.1.4. Conclusion

From the literature study conducted, different approaches on how to develop proposals for a facility layout are explored. Muther's systematic layout planning (SLP) procedure has been selected as the best procedure. Therefore, SLP procedure will be followed in designing three alternative facility layouts.

2.2. Materials Handling

One of the most important aspects in new plant development or in modification of an existing plant is through analysis of material handling (Sule, 1994). Handling material during and after processing and moving it between workstations adds no value to the product but cost. Tompkins et al. (2010) define 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. It is emphasized that for an efficient material handling system, correct amount of material should be delivered at the correct place in a correct sequence and orientation. Time, cost and methods of delivering the material are also crucial factors.

Material handling scope limits itself to the movement of material from one location to another within the same manufacturing and distribution facility. The movement can be between workstations, storage area, receiving and dispatch areas. The material includes raw material, in process material and/or finished products. An efficient material handling system reduces injuries in the workplace and minimize production time and cost.

Sule (1994) summarized the objectives of materials handling as follows;

- To increase the efficiency of material flow by ensuring the availability of material when and where they are needed.
- To reduce materials handling cost.
- To improve facility utilization.
- To improve safety and working condition.
- To facilitate the manufacturing process.
- To increase productivity.

An efficient material handling system improves the competitiveness of an organization. Material handling planning reduces or eliminates unnecessary movements and double handling of material. When planning material handling system, material handling equipment and movement are the most crucial factors to consider. Some of the dominating factors to consider when

planning material handling system are lifting requirements, weights, loads, surface condition, travel requirements and aisle space.

There exist different types of materials handling equipment. Depending on the size, shape and nature of the material to be handled, correct handling equipment should be selected. Material handling can be manual or automated. Manual handling can be define as when a human has to use hands to handle material or whereby the handling equipment depend on the physical effort of human to operate, e.g. hand trolleys. In case of an automated material handling, there is little or no interaction required from human to operate the equipment, e.g. conveyor system. Mechanization of material handling system increases operation efficiency but it required high investment cost.

Material can be grouped together to form unit loads. Unit load can be defined as a number of items arranged such that they can be handled as a single object (Sule, 1994). Unitizing material to be handled reduces the frequency of movement and it allows large quantity of material to be handles at the same time.

Mathematical models have being utilized to solve material handling problems. The objective of the models was to minimize material handling cost. Material handling cost is composed of investment or capital cost and operational cost. However, the models built did not help in selecting the correct equipment that will result in efficient handling of material but that will be optimal to purchase.

For execution of this project, material handling equipment that will optimize production flow will be selected and integrated to the facility to in order to increase production efficiency.

2.3. Spray Booths

Spray booths are utilized to provide a clean painting environment, limit hazardous material in a limited controlled environment. By restricting hazardous materials, overspray and volatile organic compounds (VOCs) are prevented to escape the controlled environment and cause fire or explosions on the nearby operations. Spray booths should be designed to allow sufficient air flow throughout the booth for ventilation purpose. According to information gathered from

futurecurewebsite (<http://www.futurecure.com/id103.html>), Paint spray booths can be categorized into three different ways, namely, cabin/booth design, airflow design and air pressure. Cabin/booth design is further categorized into open face and close face. A close face booth design has all four sides of the cabin and two doors, one for the painter and the other for the product. When high quality paint finish is required, a close face booth design is the most effective one to use. The product door can be located in the front or both in the front and the back of the booth which means that the product can pass through after processing. An open face booth design has only three walls with the front side open and there are no doors.

Airflow design is categorized into down draft, cross draft and side draft. In a down draft airflow system, air enters the ceiling through a filter of the booth and flow down into the booth. It then leaves or exhaust in three different ways, through exhaust pit design, exhaust side-wall design and/or exhaust rear-wall design. In a pit design, the pit should have a sufficient depth to allow even airflow. Side-wall design has its filtering system located on the sides of the booth/cabin. Rear wall exhaust design has the exhaust filter located in the rear/back of the booth opposite the doors. In a cross draft airflow system, air enters the booth through filters located on the doors or columns. The air flows horizontally then exhausted at the rear of the cabin or at the opposite end of the filters location. In case of a side draft airflow system, air enters on the sides of the booth through filters and it is exhausted on the opposite side of the filter (<http://www.futurecure.com/id103.html>).

2.3.1. Spray Booth Classification

According to Thomas (1999), there are two classes of spray booths associated with two divisions. Class 1 spray booth deals with flammable gases and vapours and class 2 deals with combustible dusts. Division 1 and 2 of the classes of spray booths covers the location in the classified area in which these flammable gases, vapours and dusts are handled (Thomas 1999). Class 1, division 1 regulates the design of the inside of the spray booth and ducting. Class 1, division 2 is concerned with any area located within the radius of 3 meters outside the spray booth when the extraction fans are operating. As mentioned by Thomas (1999), all equipment utilized in class 1, division 1 must be explosion proof. There should be no sparks produced by electrical equipment under normal operating condition in class 1, division 2 of spray booths.

2.3.1. Spray Booths Regulations

Spray booths are not designed as emission control devices that must comply with Environmental Protection Agency (EPA). EPA regulates the emission of volatile organic compounds such as solvent vapours which can easily diffuse through spray booth exhaust system. However, spray booth are designed to collect solid particulates. In order to collect toxic materials such as solvent vapours, acceptable methods such as a carbon adsorption system should be installed.

Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) regulate the design of the spray booths. OSHA requires that a spray booth be designed to minimum health and safety requirements. Therefore a safe working environment should be provided. NFPA enforce compliance to decisions made in installation of electrical hardware and equipment. NFPA requires that all equipment utilized inside spray booth must be fire proof. It also restricts the equipment that is allowed inside spray booth.

2.4. Automation Opportunities

According to Ron Harriesunker, production engineering manager at UCW Company, throughput can be increased if some of the paint lines can be automated. Given that there is high volume production/processing of small components at P35, an automated paint line can speed up processing and increase throughput of small components. Production time is lost in handling small components during processing. Therefore, it was suggested that small components should be hanged with hooks on trolleys during processing to make it easy for painters to handle components when they apply coating.

Different paint products are used for final coating of components. Thus if the paint line is fully automated much time will be lost in setting up the line for different coating to be applied. This constrains full automation of the paint line for all components. However, it was then suggested that only the material handling of small components during processing can be automated. It was concluded that a conveyor can be used to hang and move trolleys during and after processing.

Chapter 3: Analysis of Operations and Design Requirements

3.1. Current Facility and Operations Analysis

3.1.1. Components Types and Production Volume Analysis

Components Paint Shop is running on a 5 day production cycle with production volumes of 1100 components for 19E and 1200 for 15E locomotives. Components processed in Components Paint Shop are categorised according to their shape and size which are small components, big components, sub-assemblies and flat and straight components. The components are fabricated with 3CR12 industrial steel and some with mild steel. There are some components which are not fabricated with above mentioned material. Approximately 80% of the components processed in Components Paint Shop are small components. Therefore, there is a high volume of small components processed in Component Paint Shop.

3.1.2. Workstations Arrangement

There is no sequence in which the working stations are arranged in the plant (Components Paint Shop). The work stations are scattered in the plant. Currently the Components Paint Shop (P35) has the following working stations or equipment;

- Sorting/Receiving
- Grit blasting station (rotating nickel plate, wheel-abrator and grit blasting booth)
- Phosphate plant
- Old spray booths
- Oven
- Drier
- Dechlor tank
- Final painting area
- Red oxide area
- Primer application area

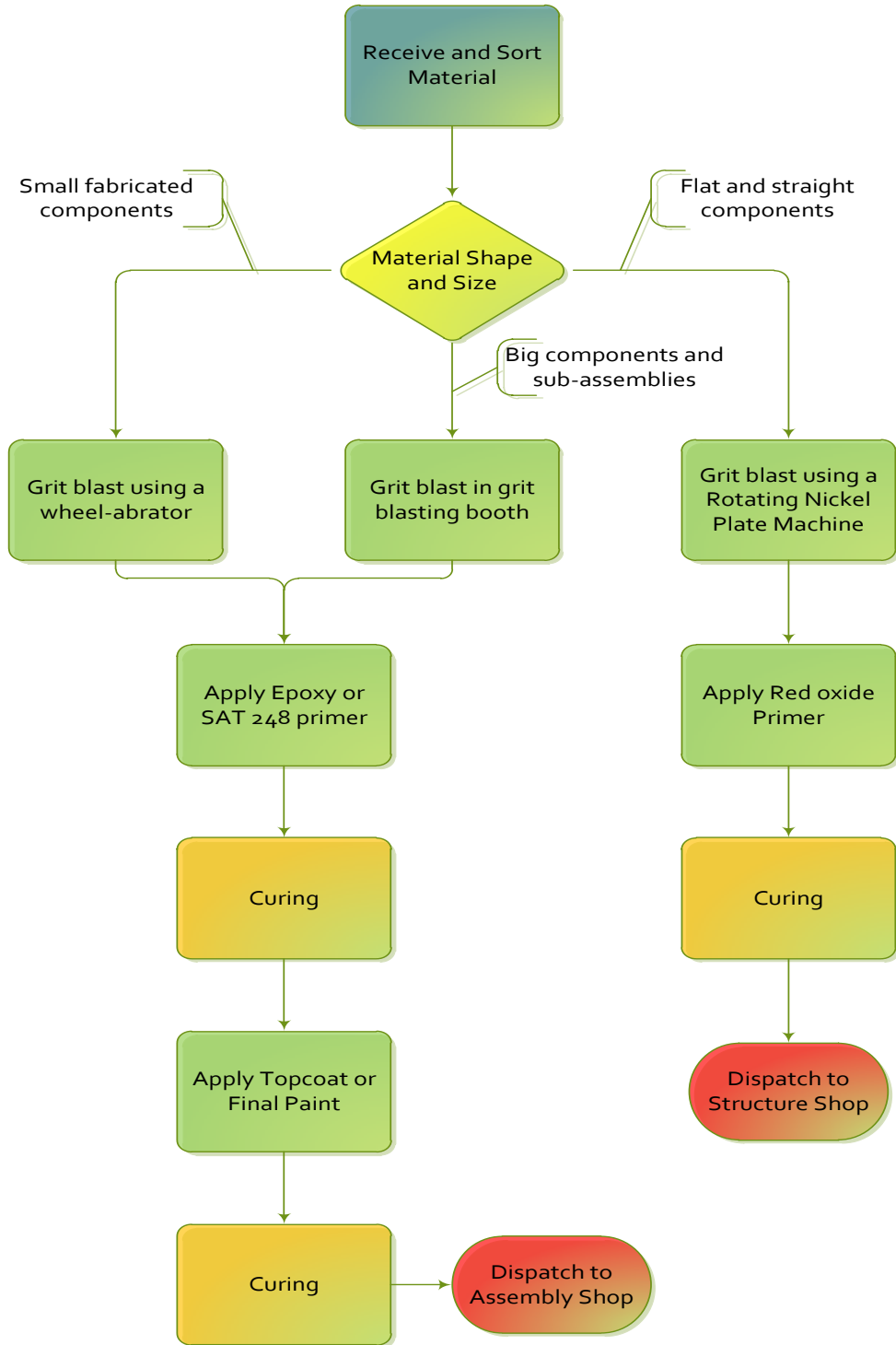
The arrangement of the abovementioned workstations is demonstrated on Appendix A. Some of these workstations are out of service. These include dechlor tank, phosphate plant, oven, drier and both of the old spray booths. As demonstrated in Appendix A there is a designated area for primer application process but it is not a spray booth or demarcated workstation.

The final painting area is under shade and divided into four stations with transparent sheets. The area is enclosed using metal sheets with open fronts. The red oxide area is an open space with no shade or cover.

3.1.3. Material and Product Flow

When components arrive at Components Paint Shop (P35), they are sorted according to their shapes and sizes. After sorting or grouping the components are then handled to grit blasting stations for cleaning (grit blasting). Small components go through the wheel-abrator grit blasting machine, sub-assemblies and big components are cleaned in a grit blasting booth and flat and straight components go through a rotating nickel plate grit blasting machine. Cleaned or grit blasted parts are then handled to priming stations. There are two priming stations, red oxide area and primer application area. Components to be welded for further processing are primed with red oxide primer, left to dry then dispatched to structure shop for further processing. Components primed with red oxide are flat and straight and are grit blasted at the rotating nickel plate machine. Other components are primed with epoxy or SAT 248 primer at the assigned primer application area. After primer application they are left to dry, then moved to final painting area where topcoat or finishing coat is applied. Coated components are left to dry before they can be dispatched to assembly shops. A detailed process flow of material through components shop is demonstrated in Figure 9.

Figure 9: P35 Process Flow



3.1.4. Material Handling Mechanism

Components are handled with the use of a forklift when delivered to P35. Small fabricated components and sub-assemblies are loaded into wooden crates, then carried with a forklift. Big components are packed on pallets then transported with a forklift. There is only one forklift available at P35 and dedicated to move components outside the facility and delivering some components into the facility. It is not used to move components between workstations inside the plant.

Inside P35 plant small fabricated components and sub-assemblies are handled with trolleys. The trolleys are used to move components between workstations and are manually operated, with workers pushing or pulling them. An overhead crane is used to move big parts inside P35. The crane can move or handle parts only between grit blasting stations. Loading of processed and unprocessed parts is done by hand.

During processing the work piece is handled or put on stands or benches. In some cases where the work piece is a small component or sub-assembly, the handling trolleys are utilized to hold the work piece. Figure 10 below demonstrates a work piece put on a stand.

Figure 10: Material Handling With a Stand



3.1.5. Current Processes and Equipment

Processes performed at P35 plant are as follows;

- Cleaning

The cleaning process is performed as a means of grit blasting. As abovementioned, there are three grit blasting stations. All parts to be processed at P35 are cleaned or grit blasted first before they can be moved to other workstations.

- Primer application

There are three different primer coating applied, epoxy, SAT 248 and red oxide primer. These primers are used as first coat or undercoating for final coating. They are also used for material protection against corrosion. Parts to be welded prior final coating are primed with red oxide primer because it can be welded with ease.

- Curing

After primer or final paint application process, the parts are left out to dry or cure. Curing can be defined as the drying process after coating. Currently there is no oven or any designated curing station. Parts are left to dry or cure at their processed or primer or paint application area before they can be moved to another processing station.

- Final painting

All parts primed with epoxy or SAT 248 primer are moved to final painting area for final paint or topcoat application. Topcoat applied serve as the protection of the material against corrosion and also for its aesthetic appearance.

Equipment utilized in P35 for material handling are an overhead crane, trolley and a forklift and those utilized for processing are spray guns, pressure pots, wheel-abrator and rotating nickel plate machine.

3.1.6. Material Control

Materials delivered at P35 are traced using a production order document attached to the batch of materials on their arrival. The document state the arrival date, plant where they are from, processes to be done, type and amount of paint to be applied, working hours required to process the material and when the material should be dispatched and to which plant. However, the production order document does not state or help with the traceability of the parts during processing. It does not help to track the production status of the parts. When parts arrive at P35

they are grouped according to their shapes and sizes for grit blasting process. Therefore the parts are not marked as to which arriving batch they belong to and to track their production status.

3.2. Gaps Identification and Analysis

In order to make improvements in P35 facility and facilitate effective and efficient production, available gaps need to be identified, and addressed. Current gaps that exist at Components Paint Shop (P35) are identified below considering two perspectives.

1. Workstation design perspective

- Spray booths – the lack of functional spray booths lowers productivity, compromise health and safety of the workers, impose potential hazards to workers, expose workers to adverse weather conditions, and it also affect or lower the quality of the products. Therefore, functional spray booths should be installed to close the gaps.
- Sanding station – there are some parts which cannot be grit blasted because of their mechanical properties. In cases where the parts are rusted, they need to be sanded to remove the rust prior to cleaning with detergents.
- Degreasing station – some parts are contaminated with grease, oil and dust when delivered at P35. These parts are only grit blasted. As it is known that grit blast cleaning only removes rust or corrosion on substrate surface, a process to remove contaminants such as grease, oils and dust should be added. Currently, only parts that are not grit blasted are cleaned with degreasers. Therefore, all parts must be degreased with chemical compounds designed to remove the abovementioned contaminants prior grit blasting.
- Drying oven – All coated or painted parts need to dry at the required temperature as per paint material data sheet prior further processing. In P35, parts are left to dry at painting stations. A curing or drying oven need to be installed to perform the curing process.
- Paint preparation or mixing room – paint is mixed at workstations by painters. All paint products require to be mixed or prepared in a temperature and humidity controlled environment and by a single person who will precisely follow the mixing procedures. A dedicated paint mixing room should be installed where all paints will be mixed by selected individuals.

- Air blowing/blasting station – after the grit blasting process, there are blasting sand residues left embedded on the surface. These residues need to be cleaned or blown with high pressure air. Therefore, an air blasting station needs to be installed.

2. Internal processes perspective

- Sanding – a sanding process should be added to clean parts that are not grit blasted and also to smooth parts prior to topcoat application.
- Degreasing – a degreasing process should be integrated with the production process flow to clean/ remove oils, grease and dust on all parts prior grit blasting.
- Air blasting – all parts that are grit blasted must be air blasted to remove blasting sand residues embedded on the substrate surface.
- Material control – all parts should be grouped according to locomotive type and further according to arrival date to ensure prioritization for processing.
- Material handling – manual material handling and double handling of materials should be minimized by acquiring handling equipment for both handling during movement and processing.

Chapter 4: Development of Alternative Layout Designs

In designing the layout, due consideration has been taken that approximately 80% of the components processed at P35 are small enough to be hanged with different hooks during movement and processing. Components coated with red oxide are only flat and straight and can be easily processed as a batch. An overhead crane and a forklift will be used to move bigger components and crates to the workstations. Materials will be loaded and unloaded with hands. To avoid redundancy, detailed analysis will be performed on the best selected layout alternative. Material handling, flow and control during and after processing will be discussed in depth for the selected alternative. Benefits of the project will also be evaluated on the final/best layout design.

4.1. Design Criteria

To ensure that an efficient facility conforming to minimum healthy and safe work environment is designed, certain criteria should be met. The facility to be designed shall meet the following criteria;

- Space utilization (How effective does the layout utilize space provided?)
- Quality of product and risk of damage to materials (How is the quality and handling of products improved?)
- Ease of maintenance (How easily can the facility or workstations be maintained?)
- Ease of material flow (Is the space enough to facilitate easier material movement?)
- Working conditions and employee satisfaction (Does the facility layout make easier for workers to do their job?)
- Compliance to regulations and standards (Does the facility design comply with OSHA, EPA and NFPA?)
- Throughput rate (Does the layout design attempt to optimize the overall production flow in order to facilitate improved or high throughput?)
- Accessibility of workstations (Are the workstations easily accessible and close to another?)
- Housekeeping (Can the facility be easily cleaned?)

- Ease of supervision and control (How easy it is to perform supervision and control workers?)
- Effect of natural conditions-land, weather, sun and temperature (How will natural conditions affect production flow and is the layout expose to such conditions)
- Employees' health and safety (How detrimental it is if workers are exposed to the facility?)
- Effectiveness of material handling system (How well is material handled?)
- Accessibility of emergency services (Does the facility design facilitate access to emergency services and routing?)
- Flexibility to accommodate unplanned production or perform emergency jobs (How sufficient is the capacity of the facility to perform extra jobs without delaying planned production?)

4.2. Systematic Layout Planning

In developing alternative layouts, the following workstations will be considered.

1. Final Paint Spray Booth
2. Primer Application Spray Booth
3. Curing Oven
4. Red Oxide Spray Booth
5. Air Blasting booth
6. Sanding Booth
7. Grit Blasting Station
8. Degreasing Station
9. Paint Store Room
10. Paint Mixing Room
11. Green Area/Rest room
12. Supervisor's Office
13. Receiving/Sorting Station

In order to facilitate a good design of the facility layout, relationships of the existing and proposed workstations are established. A relationship chart is used to depict relationships between workstations. In developing a relationship chart closeness rating and reasons behind closeness rating values are used. The relationship chart for the operation is given in Figure 11. Table 3 shows closeness rating used and associated reasons of closeness values.

Table 2: Closeness ratings and codes

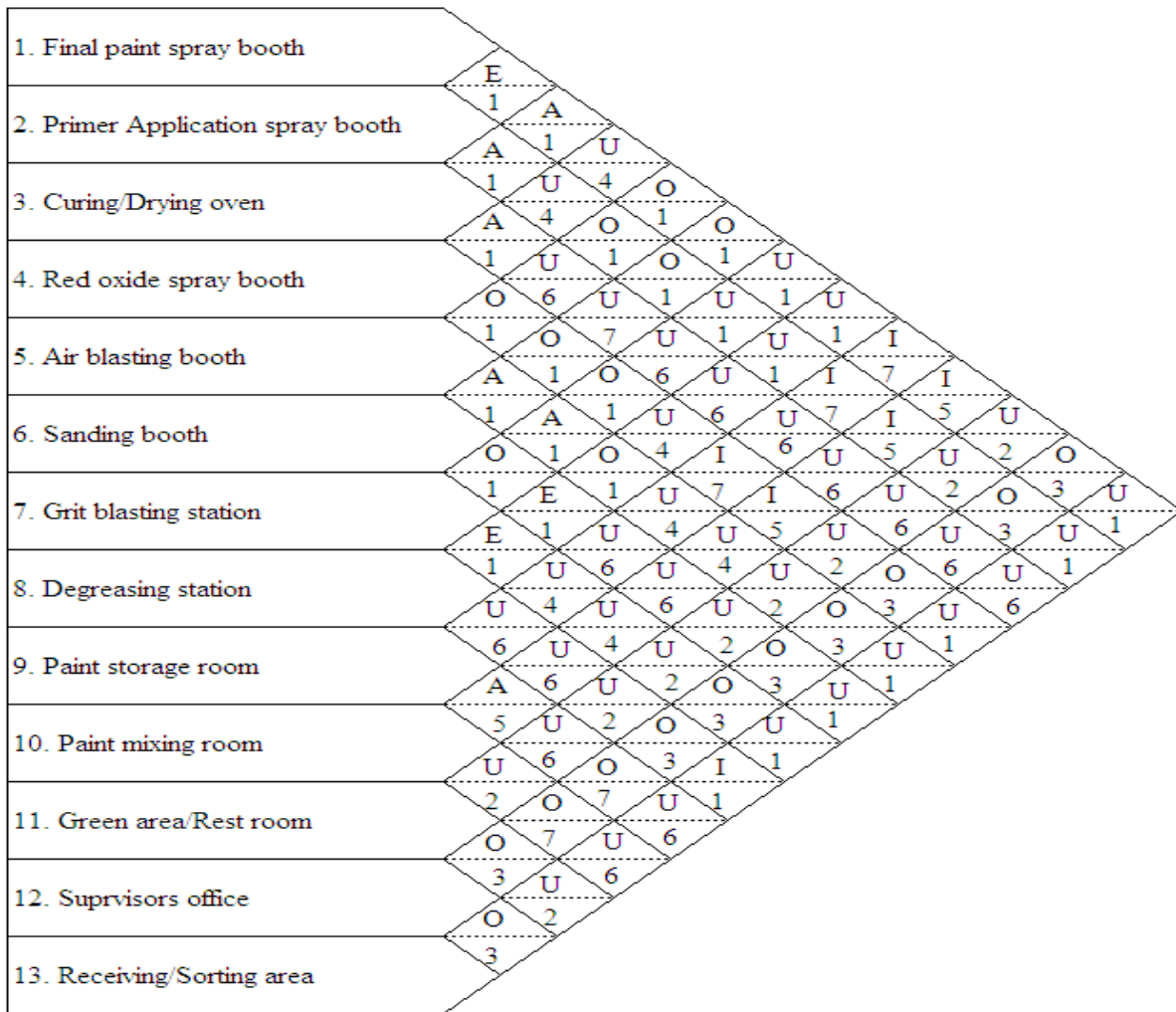
Value	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness okay
U	Unimportant

Closeness value

Code	Reason
1	Flow of material
2	Convenience
3	Communication
4	Cleanliness
5	High frequency of use
6	Low information flow
7	High information flow

**Reason Behind
Closeness value**

Figure 11: Relationship chart



A relationship chart helps in arranging workstations in order to optimize material flow and minimize handling distances. As shown on Figure 11, the important relationships are paint application spray booths and curing ovens and also between final paint and primer application spray booths. The relationship between air blasting booth and all preparation stations is important. After developing a relationship chart, a relationship diagram is the created. The relationship diagram as shown in Figure 2, demonstrates flows and relationships between different workstations. Table 4 shows lines used to represent the relationships.

Table 3: Relationship Lines





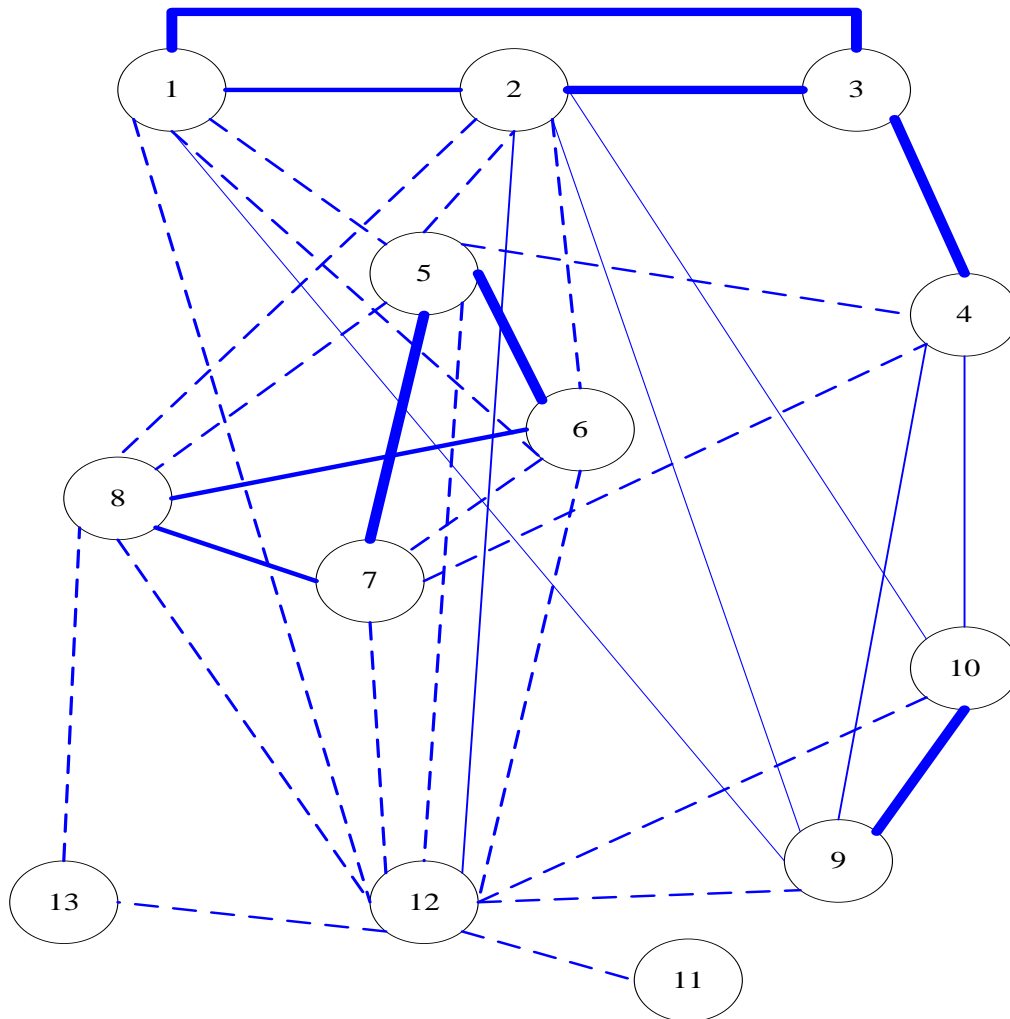
Line	Closeness
	Absolutely necessary
	Especially important
	Important
	Ordinary closeness okay
No line	Unimportant

Figure 12: Relationship Diagram



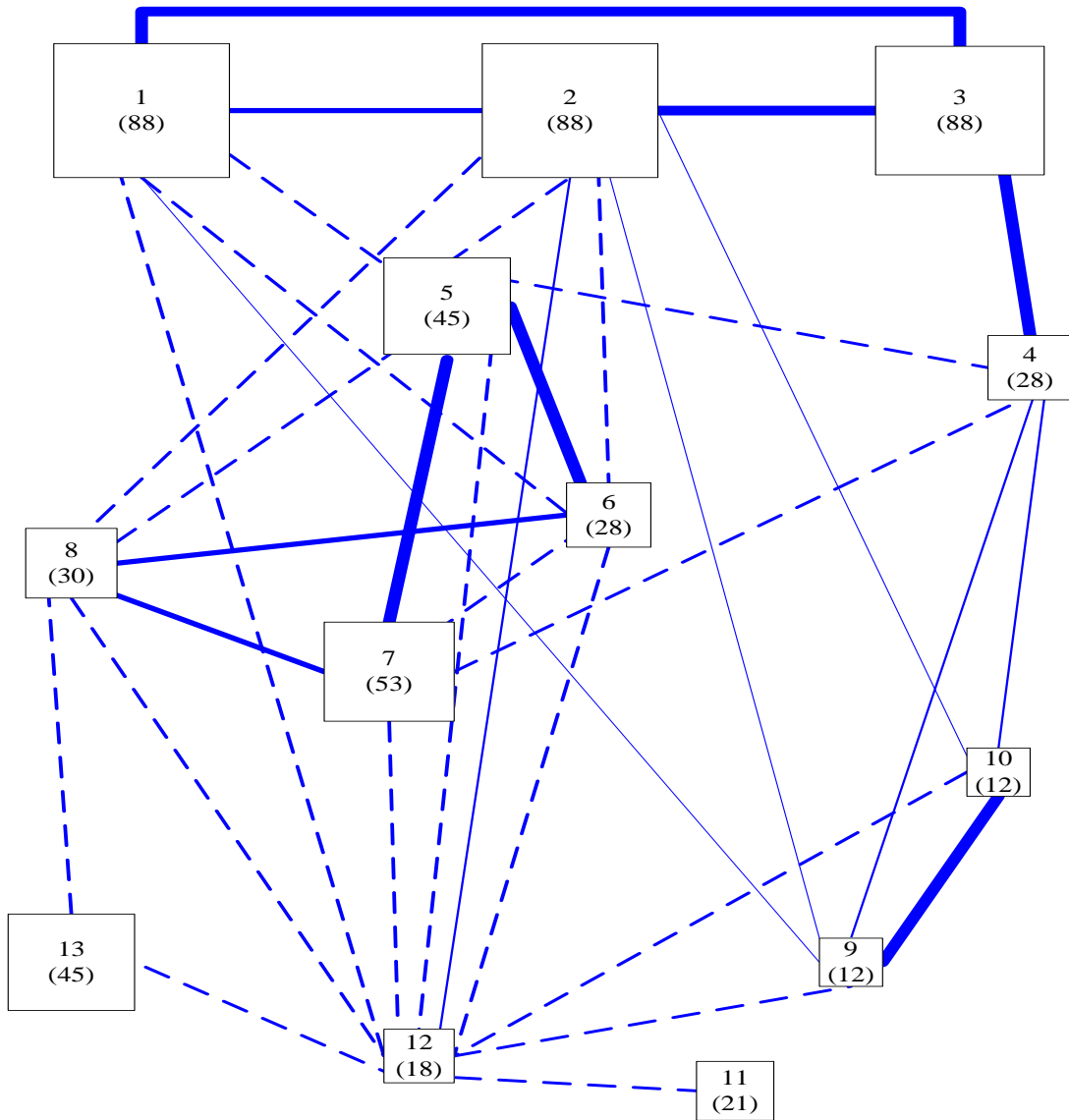
The thick lines show important relationships and flow between workstations shown together. Relationship shown with dotted lines is recommended to improve material flow between workstations. Workstations that are not linked by any line, shows that the relationship between them is not important.

Space Requirements

In order to successfully implement the proposed layout design, sufficient space will be required. Total of approximately 608.5 m² area space will be required. Currently there is 1599 m² (82 x 19.5) space available. Therefore there is sufficient space to implement the proposed solution. In the proposed solution, there are workstations that will be moved or located outside the current Components Paint Shop facility. This means that only 512.5 m² space will be required inside the facility. There is more than enough space outside the facility for which workstations located. This is computed by subtracting space required by workstations located outside the facility from total space required by proposed layout design.

An excess of 1086.5 m² space will be unoccupied. Unoccupied space will be used for movement operations such as loading and unloading of components onto trolleys and crane. The space will provide a way for movement of trolleys and safe walkways. Sufficient open space between workstations facilitates ease and efficiency of material flow and handling throughout the facility. Figure13 shows space required for current and proposed workstations configuration. Note that the unit of measure is meter squared.

Figure 13: Space Requirements



As it can be noted when adding space occupied by each workstation, it sums up to 505 m². An area of 52.5 m² will be used or occupied by a flash-off booth. A flash-off booth is utilized to ensure that all solvent vapours escape /evaporate to avoid defects as a result of entrapped moisture under coating layers. Workstation 1 space consists of space required by small components and big components spray booths. Also space required for primer application consists of space required by small components and big components spray booths. Space

occupied by grit blasting station comprise of 3 individual spaces for grit blasting machines. Space allocation shown in Figure 13 for workstation 7 is the total space required for grit blasting stations.

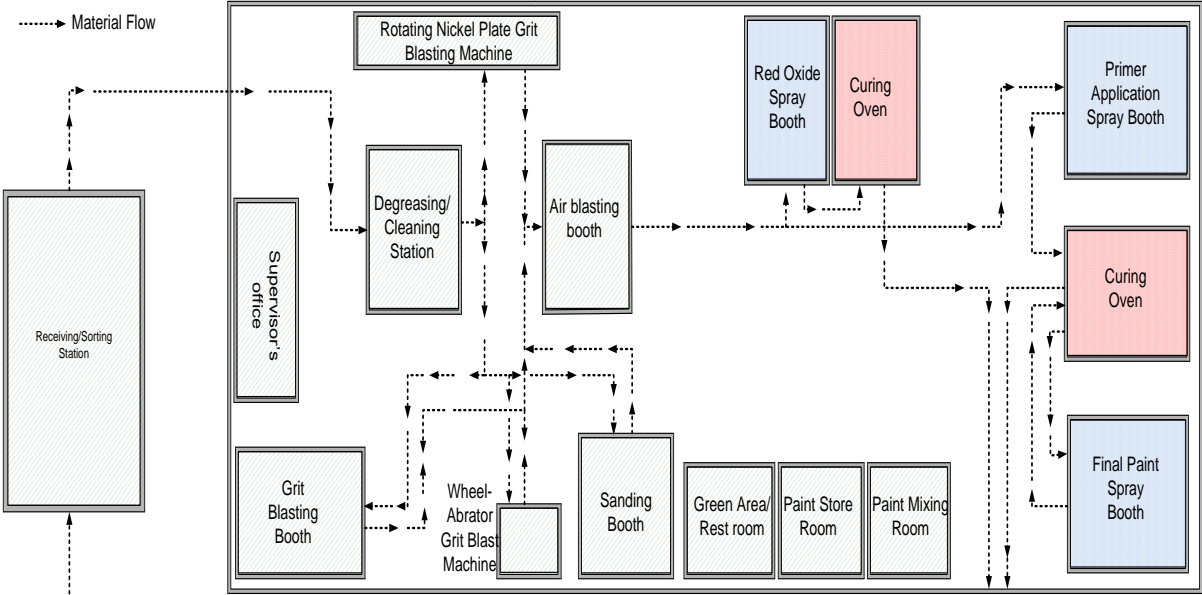
4.3. Alternative Layout Designs

The key objective of developing three alternative facility layouts is to facilitate improvement in P35 and to optimize production flow. Several workstations are proposed to be added in order to improve quality and reduce rework and waste of material. Arrangement of workstations is demonstrated on the alternative layouts.

Alternative Layout 1

Receiving/sorting station is moved outside the facility. This will ensure that all components entering the facility are sorted and can be tracked during processing. Three spray booths for primer, final paint and red oxide application are proposed to be installed. Three more workstations to the existing once are proposed to be build or installed. This includes sanding booth, degreasing /cleaning station and air blasting booth. For curing, two ovens are proposed to be installed. Red oxide coated components have their own dedicated curing oven and the other curing oven for both primed and final coated components. It is also proposed that there should be a dedicated room for mixing paint, red oxide, primer and/or final coat paint. The proposed arrangement of workstations is demonstrated on Figure 14. As can be seen on Figure 14, Alternative Layout 1 has one spray booth for final paint and one for primer application. Given the high volume of small components to be processed at each of the aforementioned spray booths and also bigger components and sub-assemblies, a bottleneck will build up and throughput will be minimized. Therefore one spray booth for primer application and final paint with one designated curing oven will not be sufficient to optimize the production flow and increase throughput. Hand operated trolleys will be used to handle material during movement and processing. An overhead crane will be used to handle bigger components to the workstations.

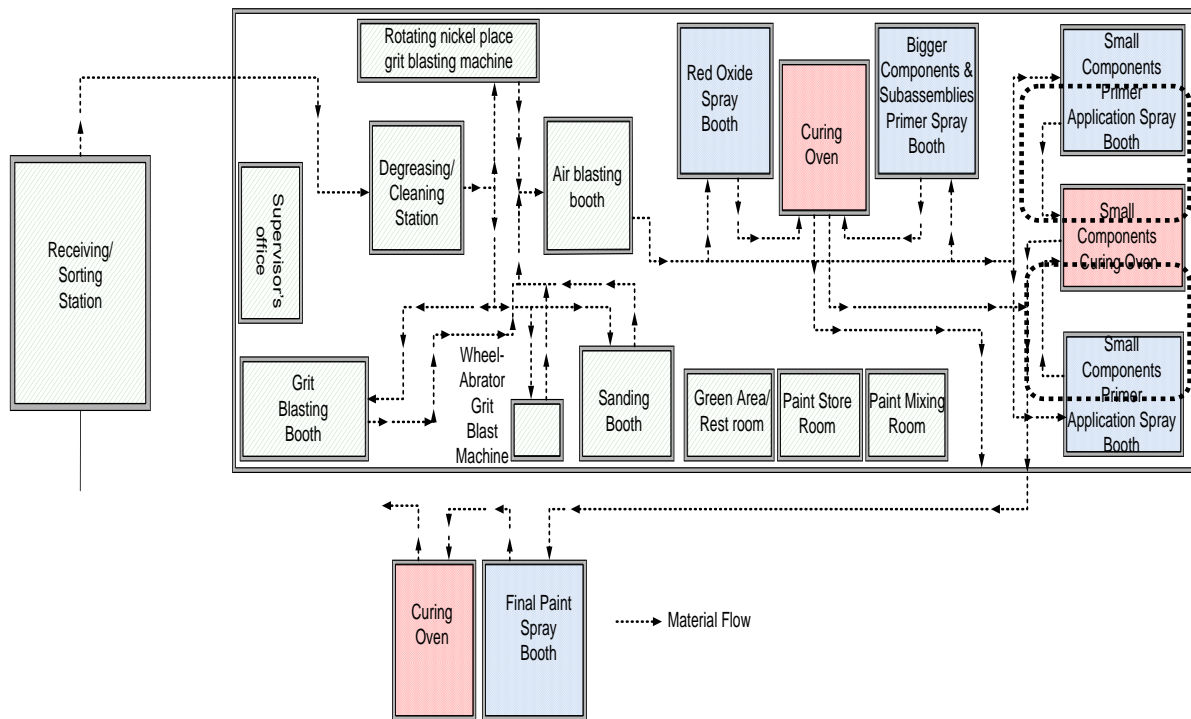
Figure 14: Alternative Layout 1



Alternative Layout 2

Alternative layout 2 has almost the same workstations arrangement like Alternative Layout 1. The difference between the two layouts is that in Alternative Layout 1 the final paint spray booth and its designated curing oven are located outside the facility as on the current layout. There is also a dedicated spray booth for primer coating bigger components and sub-assemblies. Same curing oven is proposed to be used for both red oxide coated components, bigger components and sub-assemblies. There are two primer application spray booths for small components and one designated curing oven as shown on Figure 15. Material handling of the small components paint line through primer application spray booths will be automated by means of continuous chain conveyor belts through each spray booth and curing oven to move handling trolleys. Therefore manual handling will be reduced, however loading and unloading of components will be done by hand. In other workstations, hand operated trolleys will be used to handle material. Detailed workstations arrangement on Alternative Layout 2 is shown on Figure 15.

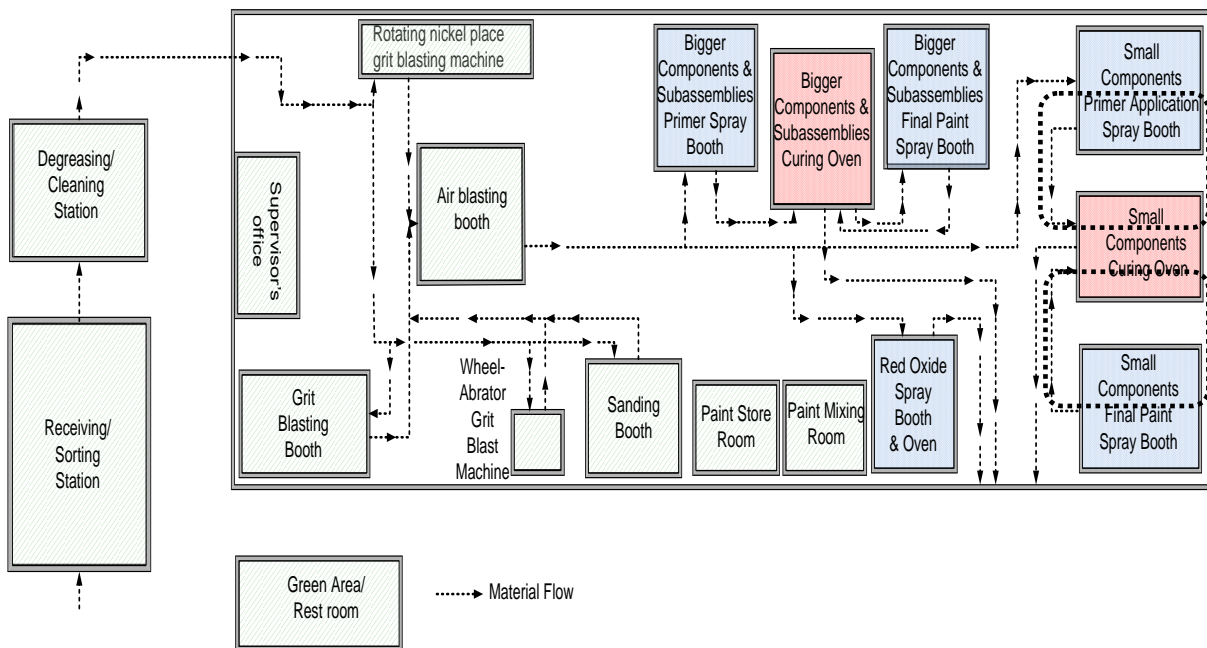
Figure 15: Alternative Layout 2



Alternative Layout 3

The degreasing workstation is moved outside the facility next to receiving/sorting station. Therefore all components will be sorted and degreased with chemical solvent to remove contaminants such as oil, grease, dust, etc. As shown on Figure 16, the green area/rest room is moved outside the facility. There is an assigned primer application spray booth and final paint spray booth for bigger components and sub-assemblies with a curing oven in between to optimize materials flow. Primer application spray booths for small components are still arranged as in Alternative 1 with an automated material handling paint mechanism. Material will be handled with hand operated trolleys at other workstations. The red oxide spray booth is now located next to paint mixing room with a build in oven or self-curing booth. A detailed workstations arrangement is showed in Figure 16, allowing ample space for movement between workstations.

Figure 16: Alternative Layout 3



Chapter 5: Layout Design Evaluation and Selection

5.1. Evaluation Factors

In evaluating the proposed alternative layouts to select the best one that will optimize production flow and meet project objective, the following factors are used as derived from Tompkins et al(2010). Please refer to design criteria for detailed explanation of the factors.

- Space utilization.
- Quality of product and risk of damage to materials.
- Ease of maintenance.
- Ease of material flow.
- Working conditions and employee satisfaction.
- Compliance to regulations and standards.
- Throughput rate.
- Accessibility of workstations.
- Housekeeping.
- Ease of supervision and control.
- Effect of natural conditions-land, weather, sun and temperature.
- Employees' health and safety.
- Effectiveness of material handling system.
- Accessibility of emergency services.
- Flexibility to accommodate unplanned production or perform emergency jobs.

The abovementioned factors are used to evaluate each Alternative Layout. Each factor is assigned a weight; each Alternative Layout will then be rated according to its design. A score for each factor is computed by multiplying a given weight with a rating. Scores for each Alternative will then be added together. Alternative Layout that has high total score will be selected to be the best. Table 5 below shows weight, rating and scores for each evaluation factor for each Alternative Layout.

Table 4: Weighted Factor Comparison

Factors	Weight	Alternative Layouts					
		1		2		3	
		Rate	Score	Rate	Score	Rate	Score
1. Space utilization	10	7	70	7	70	8	80
2. Quality of products and risk of damage to materials	10	5	50	6	60	8	80
3. Ease of maintenance	5	4	20	3	15	3	15
4. Ease of materials flow	5	3	15	2	10	4	20
5. Working conditions and employees satisfaction	8	5	40	6	48	6	48
6. Compliance to regulations and standards	6	6	36	6	36	6	36
7. Throughput rate	9	3	27	4	36	6	54
8. Accessibility of workstations	5	4	20	4	20	5	25
9. House keeping	4	4	16	4	16	4	16
10. Ease of supervision and control	4	4	16	4	16	4	16
11. Employees health and safety	10	4	40	6	60	7	70
12. Effect of natural conditions-land, weather, sun and temperature	5	4	20	3	15	4	20
13. Effectiveness of material handling system	8	4	32	5	40	6	48
14. Accessibility of emergency services	4	3	12	3	12	3	12
15. Flexibility to accommodate unplanned production or perform emergency jobs	7	3	21	4	28	5	35
Totals			435		490		583

It is evident from the weighted factor comparison of that Alternative Layout 3 scored the highest. Alternative layout 3 is the one that will best address problems at Components Paint Shop (P35). The objective of the project will be met if Alternative Layout 3 is implemented. The layout will optimize production flow by increasing productivity, ensure smooth material flow throughout the facility, improve quality of products and minimize health risk imposed to worker. The design specifications of the preferred layout ensure minimum compliance to health and safety requirements as stipulated by OSHA.

5.2. Detailed Design of Selected Layout

5.2.1. Detailed Design of Key Workstations

Detailed dimensions of proposed and current workstations are shown on Table 6. Large spray booth and curing oven refer to small components spray booth and curing oven while standard spray booth and curing oven refer to big components and sub-assemblies spray booth.

Table 5: Workstations Dimensions

Workstations	Dimensions
1. Large Spray Booth	15000 (L) x 4000(W) x 5000 (H) mm.
2. Large Curing Oven	15000 (L) x 4000(W) x 5000 (H) mm.
3. Standard Spray Booth	7000(L) x 4000(W) x 3500(H) mm.
4. Standard Curing Oven	7000(L) x 4000(W) x 3500(H) mm.
5. Red Oxide Spray Booth	7000(L) x 4000(W) x 3500(H) mm.
6. Sanding Booth	7000(L) x 4000(W) x 3500(H) mm.
7. Air Blasting Booth	9000(L) x 5000(W) x 5000(H) mm.
8. Receiving/Sorting Station	9000(L) x 5000(W) x 4000(H) mm.
9. Degreasing Station	6000(L) x 5000(W) x 4000(H) mm.
10. Green Area	7000(L) x 3000(W) x 3500(H) mm.
11. Paint Mixing Room	4000(L) x 3000(W) x 3200(H) mm.
12. Paint Store Room	4000(L) x 3000(W) x 3500(H) mm.

13. Supervisor Office	6000(L) x 3000(W) x 3500(H) mm.
14. Flash-Off Booth	17500(L) x 3000(W) x 5000(H) mm.

Spray Booths

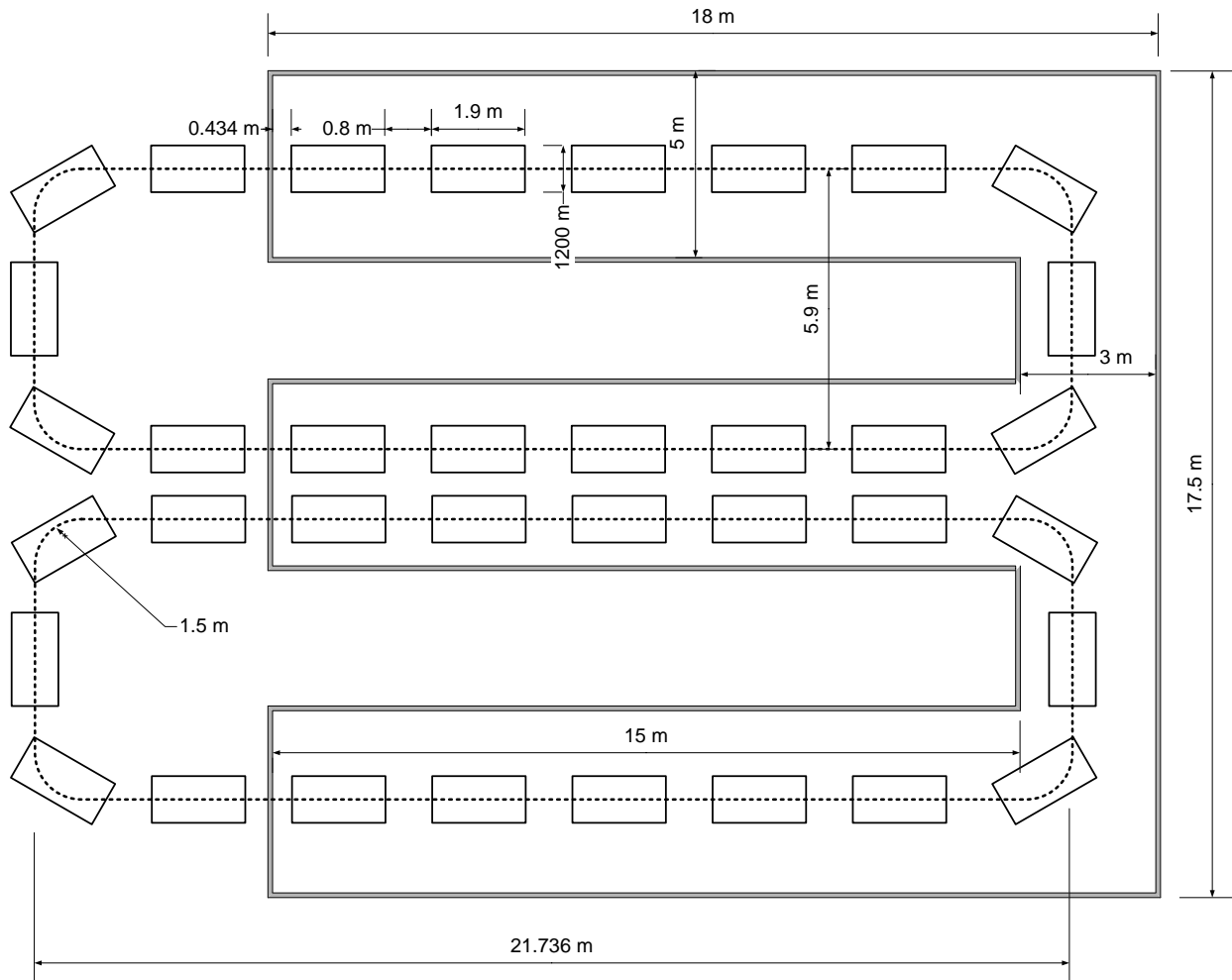
1. Small components spray booth dimensions: 15000(L) x 5000(W) x 5000(H) mm.
2. Big components spray booth dimensions: 7000(L) x 4000(W) x 3500 (H) mm.
3. Red oxide spray booth dimensions: 7000(L) x 4000(W) x 3500(H) mm.
4. Thickness of steel: 0.5 mm tongue and groove
5. Filled material thickness: EPS 70 mm
6. Semi-downdraft air filtration system.
7. Carbon filtration system.
8. Side wall extraction.
9. Four fold main-entrance door.
10. 2x safety escape doors for standard spray booths and 3x safety escape doors for large spray booths.
11. Dry baffle spray booth.
12. Total air capacity of 26000 m³/h and 0.25 air flow speed.
13. Fully electronic PLC soft touch computerized booth control module.
14. Fully electronic Belimo dumper control module.
15. Top and side lighting < 800 Lux with flame proof.
16. 5.5 kW double intake direct drive turbo extractor – 15000m³/h.
17. 2x4kW double intake direct drive turbo blower motors standard with x1000 – 24000m³/h.

Conveyor system

1. 2 x Double overhead conveyor system.
2. Tubing fabricated hangers with 150 mm pitch
3. Conveyor chain (excess in take up loads).
4. Automatic drive takes up units.
5. Track clamps.
6. Scissor pendants/hooks with 600kg load.
7. Push button control boxes.
8. Relay logic and emergency stop.
9. 57.5 m/set conveyor.
10. 20/30 minutes, every stop time.
11. Distance between trolleys: 800mm.
12. Drive speed: 0.5 m/minute.

The configuration of the trolleys on the conveyor system is shown on Figure 17. Trolleys will be loaded on the conveyor during stoppages and finished components will then be unloaded.

Figure 17: Trolleys Configuration on Conveyor System



Workstations that will be installed have the following Health and Safety features. Workstations referred to include spray booths, curing oven, paint mixing room, sanding booth and flash-off booth.

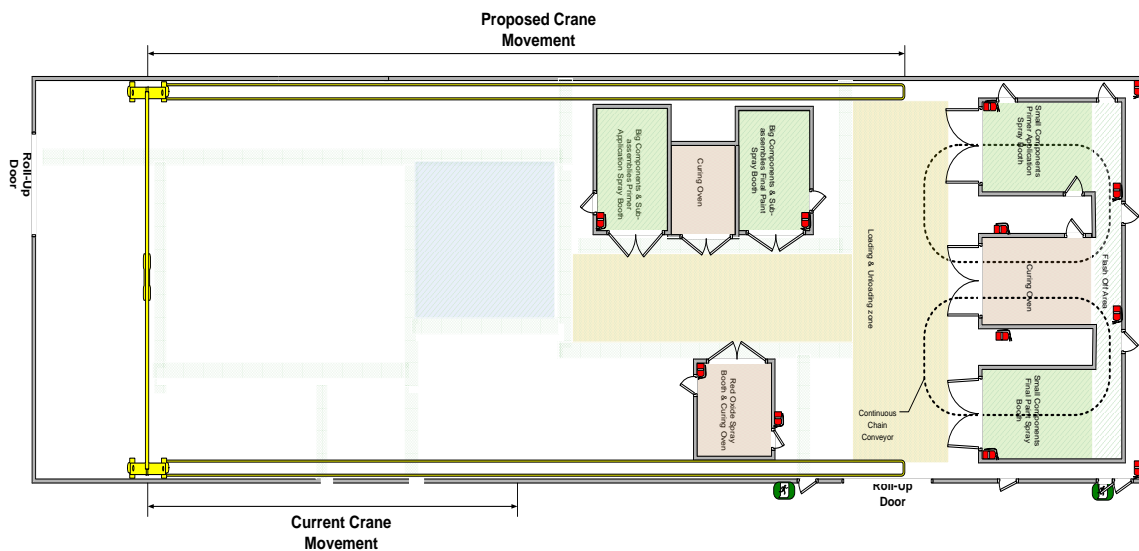
- Active carbon protection on all extraction units removing < 98% of impurities before being exhausted into atmosphere.
- Fully filtered ceiling for filtering of inlet airflow.
- Paint arrestor filter at each extraction point.
- Pre-filters at inlet of each plenum box.

- Ducting installed to 1m above closest building within 100m radius.
- Cabin is pressurized with 5% more inlet airflow than extraction.
- Semi-downdraft airflow 0.25m/s.
- Emergency stop, breakdown alarm, and motor overload protection.
- Top and side lighting <800 LUX.

5.2.2. Material handling Mechanism

Material handling method differs at some workstations. Starting from sorting/receiving station, heavy components, palletized components, big components and those handled in crates are moved with a use of a forklift. The forklift delivers the components into the facility next to succeeding processing station. The crane rails should be extended up to the primer application spray booths as shown on Figure 18. An overhead crane will then be used to move heavy and big components between processing stations.

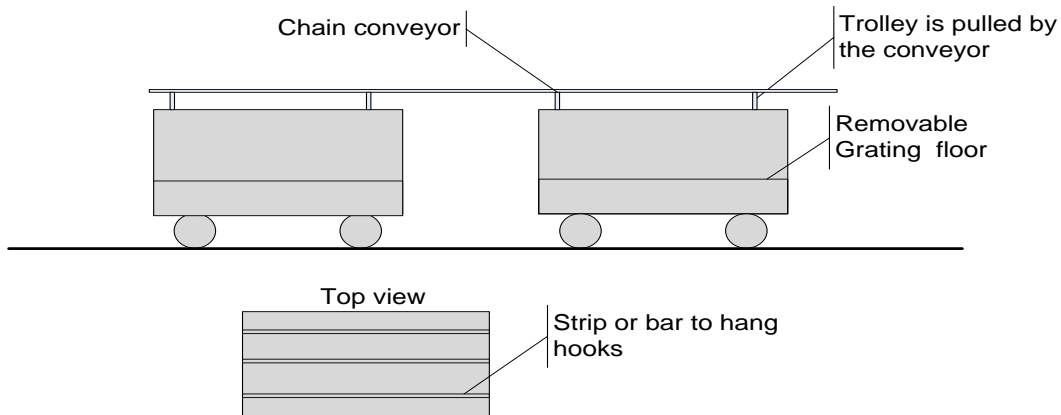
Figure 18: Crane movement



During processing components are handled with hand operated trolleys that can be pushed or pulled. At some workstation trolleys used to move components are also used to handle components during processing. The trolleys have removable grating floors to ensure sufficient space for loading. Figure 19 shows the design of the trolley

Handling mechanism for small components is automated. A chain conveyor is used to move trolleys through the spray booths and the curing oven. The trolleys are mounted onto the conveyor which pulls the trolleys. Trolleys are mounted in such a way that their wheels move on the floor. Components are hanged with hooks on the trolleys then painted. Components that cannot be hanged are put on the removable grating floor. Loading and unloading of components on the trolleys is done by hand. The path or orientation of the chain conveyor is shown on Appendix B.

Figure 19: Trolley on Continuous Chain Conveyor



5.2.3. Material Control/Prioritisation

In order to effectively control material flow in Components Paint Shop, lean or just in time (JIT) logic should be followed. Given that production at Components Paint Shop is repetitive, pull system can be implemented easily. This will require production of components be triggered by demand of those components. Demand of components to be processed should be sent to planning to generate a production order. Parts should be processes in batches or sets as required or demanded by succeeding production shop. For an example, if six bus bars are required to assemble or be welded to make a roof, then only six bus bars should be planned to be produced.

Planning should generate a production order to process only required or demanded parts. Therefore, only parts highlighted on the production order should be delivered and be processed at Components Paint Shop. After processing, finished parts should be dispatched immediately. This will eliminate inventory build-up and losing or misplacing of parts.

Production cycle time of parts should be known to ensure availability of parts to the next production plant, e.g. Assembly Shop. Production shops succeeding Components Paint Shop should place a demand on Components Paint Shop for parts that they need to continue production. Production need created in Components Paint Shop will generate demand for parts to be delivered at Components Paint Shop. This pull system should be designed or performed to ensure that needed/requested parts are delivered at concerned production shop a day before actual processing of the parts to ensure availability on their processing day. On a five days cycle, for an example, if parts are needed in day 5 at Assembly Shop from Components Paint Shop, parts should be delivered in Components Paint Shop on day 2 and dispatched to Assembly Shop on day 4 to ensure availability on day 5. This will depend on how long it takes to process and finish the parts. Therefore, sufficient time should be allowed for processing of parts. Each production shop will provide such information to planning. The sequence or logic should also apply to other production shops involved in the supply chain of the parts.

Collaborative planning and integration of inbound and outbound logistic system of individual production shops will create an efficient supply chain. Waste, inventory, unnecessary production and movements will be eliminated. This will ensure parts traceability throughout the supply chain. When parts are received at a certain production shop, it should be marked or indicated on the production order that parts are received. Also when parts are dispatched, it should be indicated. A production status form should be created and be attached to the batch of parts being processed. Current processing station should always be indicated on the form to ensure traceability. Also when parts are handled to another workstation it should be indicated that they have been dispatched from the previous workstation.

In summary, to ensure minimum inventory and ease of parts traceability, parts should be delivered in correct quantity at the production shop requested them a day before processing. No extra parts should be processed. Delivery of parts should allow sufficient processing time at the current production shop to ensure that parts are dispatched or received on time in the succeeding production shop. Workstations processing capacity will dictate commencement of processing. If

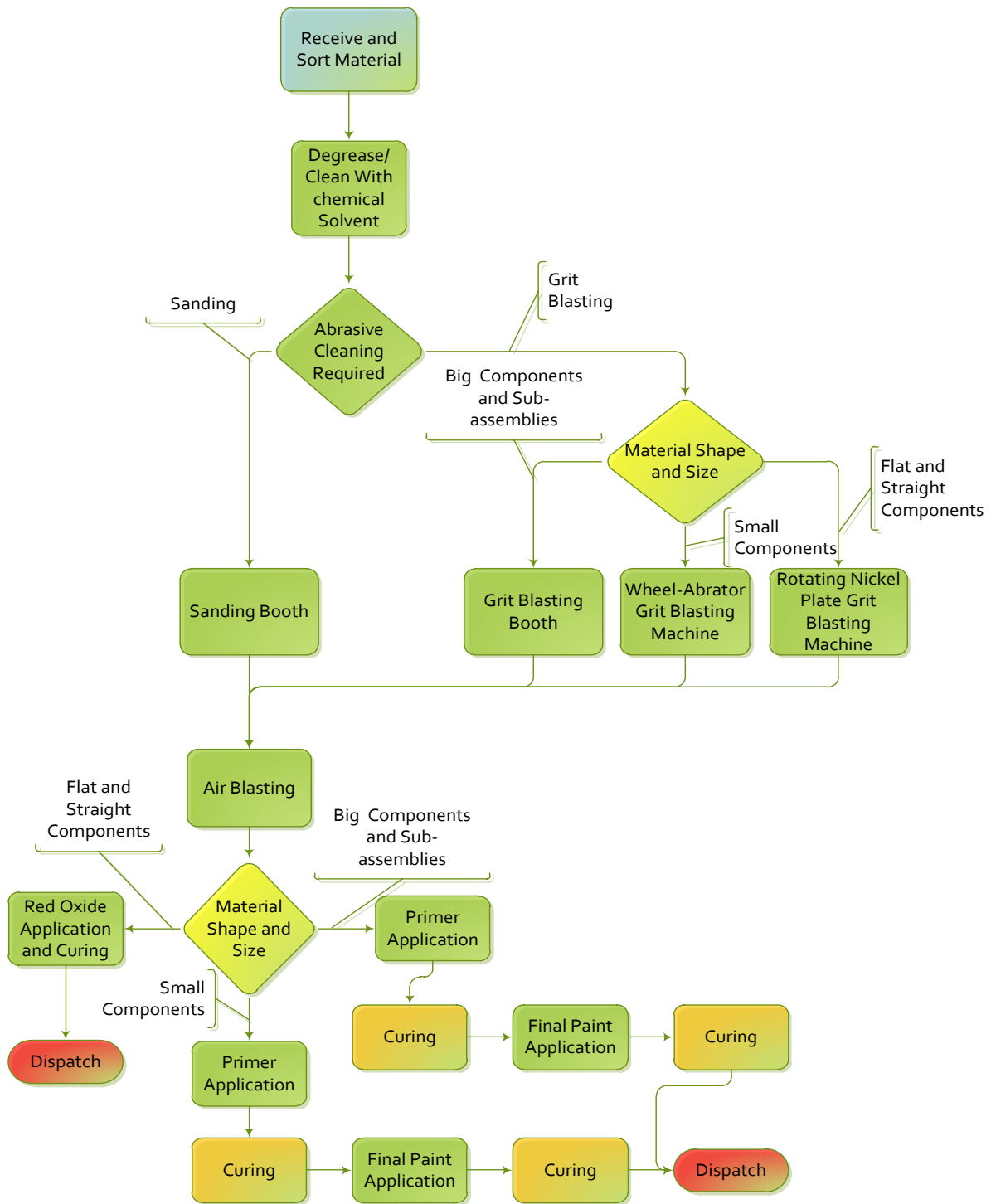
the required demand is double the shop processing capacity per day, then parts should be replenished or delivered on time to allow double processing or double processing cycle.

5.2.4. Material Flow

Components are received and sorted according to shape, size and arrival date. After sorting, components will then be moved into degreasing station to remove contaminants by means of cleaning with chemical solvent and a high pressure steam. Degreased components are then handled into the facility for further processing. Depending on sizes and shapes components are distributed to relevant abrasive cleaning stations, namely, grit blasting and sanding stations. Components that are not grit blasted are light sanded to remove corrosion or rust. After abrasive cleaning all components are blasted/blown with high pressure air blasting nozzle. Air blasting process will remove sanding or grit blasting residue left embedded on the components surface leaving a clean surface.

Big components and sub-assemblies are handled to their assigned workstations for primer application, curing then final paint application and curing again. Finished products are then dispatched. Flat and straight components are coated with red oxide at the assigned spray booth, wait to cure then dispatched. Small components are handled to loading zone, loaded on trolleys using hooks at their dedicated spray booth for primer application. The chain conveyor will then go through the spray booth for coating and then into a curing oven for drying. After curing components are unloaded, handled to final paint application spray booth then loaded on the trolleys. After curing, components are dispatched. Figure 20 shows a process flow of Alternative 3, the arrangement of workstations is demonstrated in Appendix B.

Figure 20: Proposed Process Flow



5.2.5. Production Efficiency

Most paint defects at Components Paint Shop (P35) are caused by poor preparation of the substrate surface prior to coating. Such preparation cause or minimise adhesion of paint on components surface which eventually leads to paint delamination. Therefore, proper preparation of the substrate surface by means of degreasing, grit blasting or sanding and then air blasting will ensure a well prepared surface for coating and it will increase adhesion. Defects related to poor surface preparation will be minimized and/or eliminated. This will improve quality of the products.

Productivity will be increase by introduction of proper dedicated workstations for each process done to minimise delays or bottleneck build up at workstations. Introduction of curing oven will ensure that painted components do not have to be left out to dry in spray booths before painting other components. Therefore an effective production flow will result. Unnecessary processing delays will be mitigated. Automation of small components material handling during processing will optimize production flow by ensuring a continuous processing of small components since they are required in high volume. Throughput will increase to meet the required production demand.

Preparation/mixing of paint also have an impact on the quality of the products. If paint is not prepared according to specifications, in a controlled environment with required temperature and humidity, it is likely to cause defects on painted products. Proposing a dedicated paint mixing room will ensure that paint is mixed according to the Material Specification Data Sheet (MSDS) of paint product used. Paint defect related to preparation of paint will be eliminated.

The work environment where painting is performed has an impact on the finish of the coating. Spray booths will provide a controlled environment which is free of dirt and other foreign particles that might embed on the substrate surface during painting. Painting parameters such as temperature and humidity plays a significant role in determining the quality of the paint finish. Therefore installation of spray booths will ensure that all painting parameters are controlled and within specification as noted in the Material Specification Data Sheet (MSDS). A safe and clean work environment will increase worker morale which in turn will increase productivity. Health

risks associated with working in a painting environment will be minimized. In cases of emergency evacuation, emergency routing is demarcated as demonstrated on Appendix D.

5.3. Implementation Cost and Plan

5.3.1. Implementation Cost

Different companies and contractors were requested to submit quotations for installation and upgrading of proposed workstations and performing other activities to successfully implement the proposed solution. Table 7 shows the estimated cost quoted to perform all activities necessary to implement the solution. An estimated total amount of R5 818 268 is required to implement the proposed solution. Costs of decommissioning equipment, moving and upgrading some workstations and equipment are included. Quotation for spray booths, sanding booth, air blasting booth, curing ovens, mixing room and double overhead conveyor installation has been submitted by ZIPSA Trading cc. There are some minor activities that will be performed by Maintenance department within the company and are not quoted.

Table 6: Implementation Cost

Description	Quantity	Unit Price	Amount
1. De Havilland Large Spray Booth	2	R 495 000	R 990 000
2. De Havilland Large Curing Oven	1	R 495 000	R 495 000
3. De Havilland Standard Approved Spray Booth	2	R 158 900	R 317 800
4. De Havilland Baking and Spraying Booth	1	R 305 600	R 305 600
5. Double Overhead Conveyor System	2	R 674 980	R 1 349 960
6. De Havilland Standard Approved Oven	1	R 158 900	R 158 900
7. De Havilland Paint Mixing Room	1	No Charge	No Charge
8. Paint Mixing Bank For Mixing Room	1	R 48 600	R 48 600
9. De Havilland Sanding Booth	1	R 122 900	R 122 900
10. G11 shot Blast Booth	1	R 957 890	R 957 890
11. Flash-Off Booth	1	R 689 450	R 689 450
12. Installation	1	No Charge	No Charge

13. Removing Of The partition Wall	1	R 2 340	R 2 340
14. Moving Phosphate Plant and overhead crane	1	R 4 869	R 4 869
15. Filling Area With Concrete	1	R 5 880	R 5 880
16. Removing Infrared Oven	1	R 3 296	R 3 296
17. Removal Of The Old Spray Booth	2	R 13 897	R 13 897
18. General Levelling Of The Floor	1	R 2 856	R 2 856
19. Overhead Crane Upgrade	1	R 86 860	R 86 860
20. Removal of Dechlor Tank	1	R 3 190	R 3 190
21. Erect Sorting and Cleaning Area Structure	1	R 46 980	R 46 980
22. New Trolleys	40	R 5 300	R 212 000
Total			R 5 818 268

Note that large spray booth refers to small components spray booth and standard spray booth refers to big components and sub-assemblies spray booth

5.3.2. Implementation Plan

Implementation plan for the proposed solution is shown in Appendix D. Workstations and equipment need to be decommissioned or removed as part of the implementation. There are also workstations that will be rearranged. The equipment that will be decommissioned is out of service and some not in use. Appendix D shows all the major activities that need to be done and parties responsible to successfully implement the proposed solution.

The solution implementation is planned to take approximately 26 weeks, provided that there are no delays during the process. December holidays will be used for decommissioning of out of service equipment and workstations. Production stops on 9 December 2011 and resume on 9 January 2012. This is the result of the official shut down that will take place at the working site for December holidays.

Due consideration of production during implementation has been taken into account. Activities to be done during implementation are planned in such a way that production will not be required

to stop. Activities that will cause massive distraction or interruption on production, e.g. decommissioning of equipment and workstation and rearrangement of some workstations, will be performed during December holidays and on weekend if there is still production taking place.

5.4. Testing

The proposed facilities design solution can be tested after implementation. The testing process can be done by monitoring and studying the production flow of the plant for a certain time period. Observations made should be compared with throughput before the implementation of the proposed solution design. Previous state and current state of the facility processes, working conditions, quality of products and productivity should be compared in order to recognize improvement facilitated by the proposed solution design. Therefore the solution has to be implemented in order to be tested and validated.

Chapter 6: Conclusion and Recommendation

6.1. Conclusion

The best selected layout, Alternative Layout 3, will optimize production flow in Components Paint Shop and provide workers with good working conditions. Evaluation of Alternative Layout 3 based on design criteria for the Components Paint Shop facility, it satisfies all criteria. Therefore increased productivity and other production related long and short term benefits will result upon implementation of the proposed solution.

As it is the company's objective and goal to achieve efficiency in their production, improvement of its production facility and processes is critical. Improved production facility and processes facilitate good worker moral or happy employees which will enhance effectiveness and efficiency in production flow. High productivity and profitability will therefore result.

In completion of this project it is found that good production facility facilitates production efficiency. To achieve such an efficient production environment, high capital expenditure is required. Therefore the company should be willing to investment millions to improve its facility and optimise production flow. Efficient production flow results in savings from rework, eliminate scrap and reduce employees exposure to hazardous working environment thus eliminate compensation costs required in case of work related injuries, illnesses and death.

In conclusion, implementation of the proposed solution not only will improve production efficiency but it will strengthen the company's relationship with its customers by providing them with reliable service and delivery of quality products. Implementation of the proposed upgraded facility determines success of the company in manufacturing industry by enhances its competitive advantage.

6.2. Recommendation

In order for Components Paint Shop to produce quality products and acquire optimal production, it is highly recommended that it invest in improving and upgrading its production facility and processes. Although the proposed solution requires large capital investment, it will however in a long run benefit the company. Improved productivity, elimination of rework, avoiding of lawsuits by OSHA, EPA, NFPA and other government organizations regulating painting environment are benefits the company can have.

As discussed earlier that Components Paint Shop facility does not comply with minimum requirements of OSHA and NFPA, severe consequences might or will result that will negatively affect the company. Official shut down of the production plant by Fire Marshall and/or OSHA officials is one of the severe consequences. If the plant is shut down, the company will be forced to upgrade its facility and at that point there will be loss incurred due to stopped production as a result of the shutdown.

Analysing the current state of Components Paint Shop facility, it is evident that large costs are incurred as a result of rework and worker injuries and/or illnesses related to the work environment. Costs incurred as a result of rework includes scrapped material cost, processing material cost, labour cost and other utilities such as electricity, water, paper, etc. It has been observed that rework cost is higher than initial cost of producing the products.

In a long run when considering all costs incurred as a result of poor facility, it perfectly justify capital investment required to implement the proposed upgraded facility. Return on this investment will be recovered or realized in a long run after implementation. Savings that will result or be made by eliminating cost of rework, compensation costs and lawsuit costs also justify the investment in upgrading the current facility.

The newly improved facility layout design will result in the following expected benefits.

- The working environment that will meet minimum health and safety requirements

- Improved material handling system that will minimize manual handling by workers, handling cost and double handling of material during processing
- Improved productivity and increased output with an agile production system
- A better user friendly working environment
- Improved quality of the final products
- Improved delivery performance through efficient material control (no parts lost, misplaced or unidentified) and prioritisation of production orders

Possible quantifiable benefit and saving are:

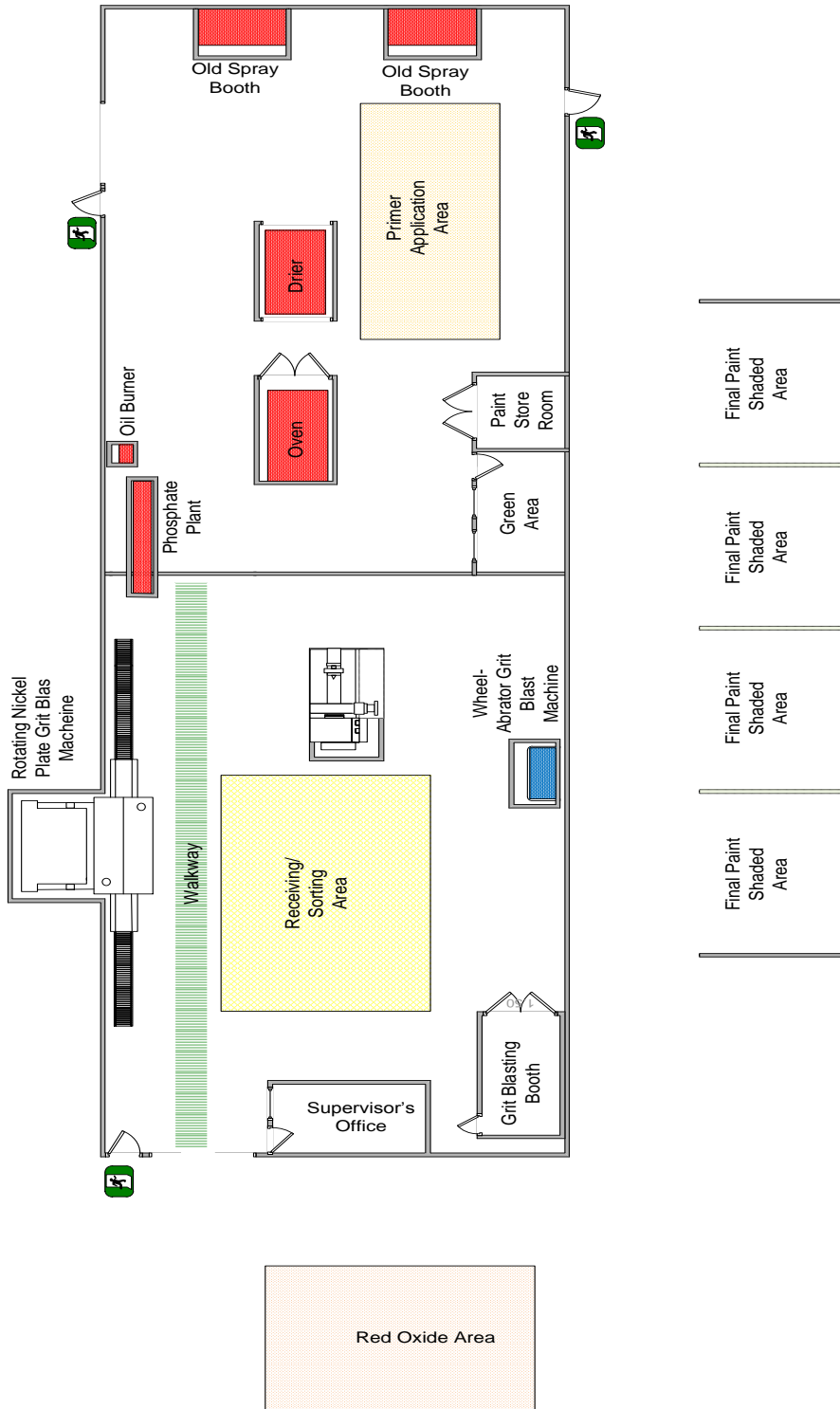
Table 7: Quantifiable Benefits and Savings


Quantifiable benefits	Possible savings
• Improved quality of products.	Rework cost (labour, material and utilities).
• Efficient material handling and flow.	High productivity and throughput (at low labour cost, cycle time and labour hours reduced).
• Good material control.	Elimination of cost to replace damaged and lost parts.
• Compliance to OSHA and NFPA.	Elimination of law suits and non compliance fines.
• Good work environment.	Minimised compensation costs(no injuries and work related illness and death)
• Elimination of scrap material.	Material replacement cost
• Balanced workflow.	Reduced labour costs (line balancing to balance head count).

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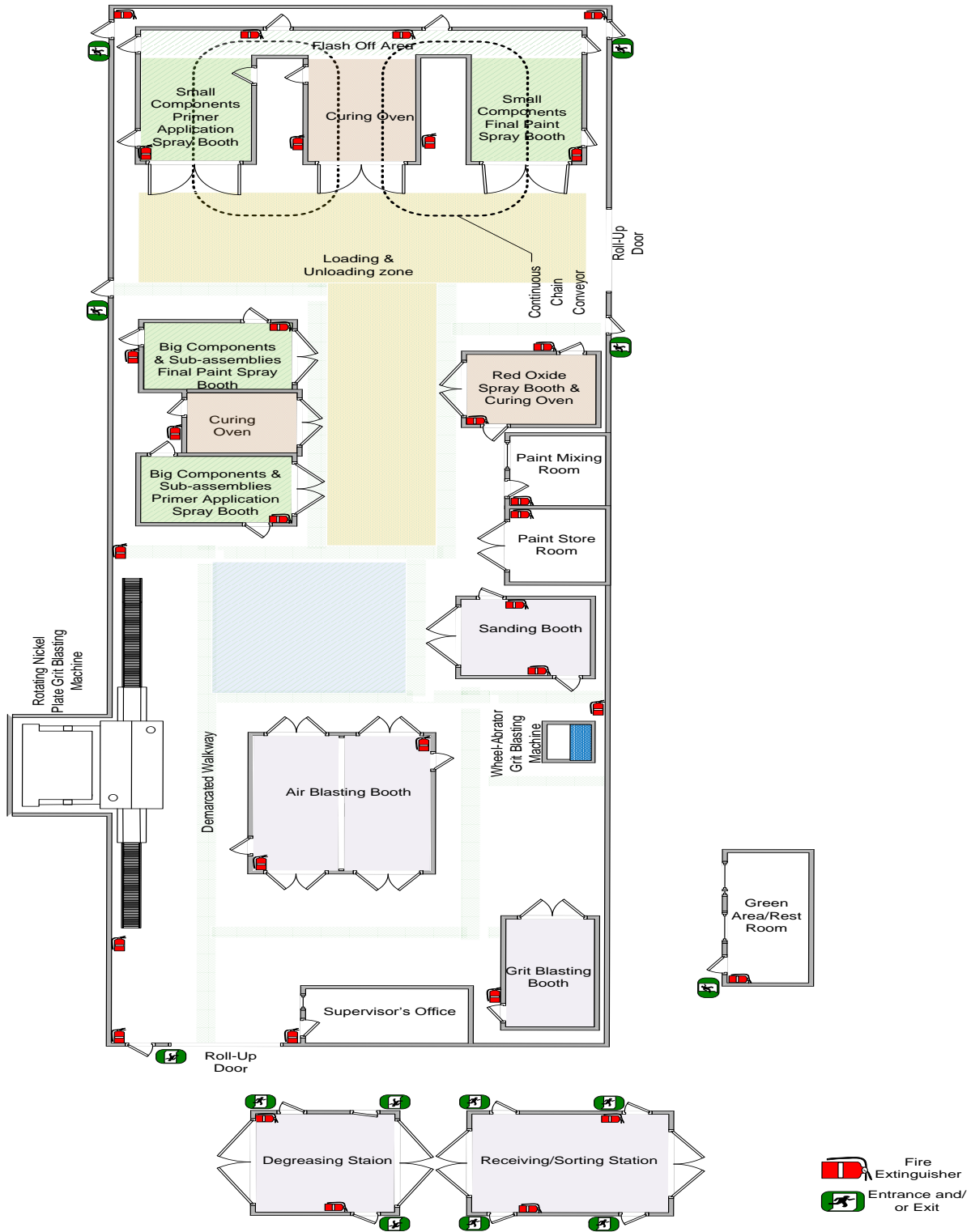
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Appendix A: Current Layout



 Emergency exit

Appendix B: Proposed Layout



Appendix C: Emergency Evacuation Routing

