OPTIMIZING FACILITY LAYOUT THROUGH SIMULATION

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Executive Summary

Clyde Bergemann Africa would like to make it possible to manufacture specialized equipment used in their pneumatic systems in-house. To accomplish this, a new workshop and its layout have to be designed. The through put time of the production of the vessels will be calculated by doing comprehensive time studies and thus determining the cycle time.

By manufacturing the vessels on the premises the company can apply more rigorous quality and job control in terms of the quality of the vessels, controlling the schedule and the cost of the new workshop. This will result in keeping CBZ at the fore front of the field and improving customer satisfaction.

The following aspects of designing a new facility were addressed:

- Process Flow
- Equipment needed
- Process Analysis
    - Area requirements
    - Location of the different departments
    - Material Handling
    - Cycle times

The techniques learned in facility design, productivity and manufacturing systems were used to assist in solving the problems stated above.

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List of Abbreviations

CBZ – Clyde Bergemann Africa (PTY) LTD

CORELAP – Computerized Relationship Layout Planning

ROA – Return on Assets

TCR – Total Closeness Ratio

SLP – Systematic Layout Planning

1. Introduction and Background

Clyde Bergemann Africa (Pty) Ltd is a sister company of the Clyde Bergemann Power Group Inc. The primary aim of this company is to assist the power generating industry in improving the efficiency and effectiveness of thermal processes by utilizing the latest technologies available in this field.

Clyde Blowers South Africa (Pty) Ltd was formed in 1976 as a subsidiary company of Clyde Blowers LTD, a company based in the United Kingdom. Clyde Bowers South Africa and Clyde Blowers UK are known for the improvement in boiler efficiency. This is achieved by implementing soot blower technology as well as Online Boiler Cleaning Technologies.

Forces were joined with another UK based company, Macawber UK LTD, to form Macawber South Africa (Pty) Ltd in 1980. This newly formed company specialized in pneumatic conveying systems and bulk material handling. After 30 years Clyde Bergemann Africa is still a leader in pneumatic conveying field.

The pneumatic conveying of bulk granular material in the metal, mineral and industrial sectors is what Clyde Materials Handling Africa specializes in. Due to the capabilities of the Clyde Materials Handling Africa's conveying system, this diversity is possible. These systems can handle anything from a few kilograms per hour to 300 tons per hour. The systems can achieve these rates at over 3000m. The system can convey a number of different granular sizes ranging from dense phase to lean phase and even advanced vacuum conveying.

Clyde Bergemann remains the leader in pneumatic materials handling and boiler efficiency with branches all over the world. The service Clyde provides ranges from equipment supply to total turn-key solutions inclusive of design, installation, commissioning and training.

Clyde Bergemann Africa (CBZ) has recently started to look into alternatives for their current equipment manufacturing policy. Currently they import all the needed material to assemble the equipment but it was found, after all the needed studies were done, that this is no longer the optimal solution. The company has decided that it will be more beneficial to manufacture the equipment in house.

With the needed facility layout and process analysis the transition from 'assembly only' to 'manufacturing from beginning to end' can be as smooth as possible.

2. The Problem

After investigations by the company regarding the equipment manufacturing policy it was decided that it will be more feasible to manufacture the parts used in the assembly line themselves instead of importing it from overseas manufacturers. The needed studies accompanied the investigation and confirmed that the self-manufacturing is the optimal solution.

With the needed facility layout and process analysis the transition from 'assembly only' to 'manufacturing from beginning to end' can be as smooth as possible.

3. Project Aim

The aim of this project is to assist Clyde Bergemann Africa in their new venture to manufacture their equipment in house by optimizing the facility layout through simulation.

Objectives in realizing the aim:

- Determine the best possible facility layout through simulation
- Establish the throughput time by a comprehensive process analysis
- Simulate the process to determine whether the deadlines will be met

4. Project Scope

The first part of the project will entail an extensive literature study. The study will focus on how similar problems were solved with the help of simulation as an auxiliary tool. The relevant information gathered through the study will be incorporated into the project.

Part two will be concerned with the facility layout section of the problem. In this part the following must be determined:

- The different departments involved in the manufacturing process
- The machinery needed
- The area requirements for each department
- Process flow through the facility
- Location of each department within the facility
- Material handling between the departments
- Storage of inventory
- Routes for storage area to the workshop floor

When the activities listed above have been completed step 2 can commence. This entails determining the through put time of the manufacturing process. This is needed to determine the date for manufacturing to start to ensure that CBZ meets the deadlines set by the clients.

The final part of the project will be to model the manufacturing system to ensure that the recommendations are plausible.

The implementation and evaluation of the manufacturing system falls outside the project scope.

5. Literature Review

5.1 Facility Planning

5.1.1 Facility Planning Defined

How the activities in a facility interact with each other to achieve the goals of a company is the definition of facility planning. In a manufacturing facility the design supports the production (Tompkins 1984). When a facility is optimally designed there will be a noticeable increase in both effectiveness and efficiency of both the workforce and the production line. The increase in productivity will help the company to stay at the forefront of the field and ensure a competitive edge.

The field of facilities planning has moved forward considerably in the last few decades. In the beginning the main goal of facilities design was to minimize the distance travelled between the different workstations. The quality of the design depended wholly on the experience of the layout analyst (Gopalakrishnan, Turuvekere, Gupta; 2004; 200).

5.1.2 Objectives of Facility Planning

The main aim of designing a facility from the ground up or redesign an existing facility is to ensure the company has a competitive advantage. Although this is the most important goal there are other objectives. One of the most important objectives of facility planning is to ensure that the customers are satisfied with the service or products they receive. Other goals such as in increase of revenues are aligned with customer satisfaction (Tompkins 2004). Thus when the customer satisfaction objective has been reached successfully, the company's other goals will fall in place.

When a company is designing or redesigning a facility the following additional goals must be achieved to ensure the company will be a leader in their fields. All these additional goals can be achieved through proper facility design (Tompkins 2004):

- Maximize the speed with which the customers are served
- Keep the workforce happy by having a facility that complies with the Occupational Health and Safety Act
- Make maintenance of the equipment and machinery easy through an adaptable facility
- Ensure the optimal use of the available space by effectively utilizing equipment, machinery and people
- Improve the material handling, material control and good housekeeping can support the organization's vision

5.1.3 Necessity of Facility Planning

Why is facility design needed? Without the right facility design the company can't function at its optimal level. This will result in a loss on the return on assets (ROA), a de-motivated workforce, an increase on capital expenditures and a manufacturing floor that can't meet the customers' requirements to name a few. According to Reinders (Reinders 2008) facility design will prevent the following:

- Ineffective work methods
- Changes made in the design of the product to accommodate the layout
- Occurrence of bottlenecks due to the unproductive layout of the facility
- Health and safety hazards
- Possible moral problems
- Unusually high costs

The design process of a new facility relates to only 5 percent of the total production cost but effects 70 percent of the manufacturing cost (Sule, 1994). Although the initial design phase takes more time and capital, the company will benefit in the long run. The extra attention to detail in the design phase will result in a facility which assists the manufacturing process to reduce rework time and the ease of production and assembly. A facility which inhibits the production process incurs additional costs in manufacturing throughout its life cycle. If a problem appears or is noticed after the designs have been released rectifying the problem could be costly.

5.1.4 Layout Identification

Facility planning is a continuous process with a number of operations that must take place to achieve optimal results. According to Tompkins et al (Facilities Planning 3rd edition 2003) these operations are:

- Determining plant location
- Plant design
- Plant facility system
- Plant layout
- Material handling

The first two operations are excluded in this project.

Before decisions can be made on the facility layout the product that will be produced must first be categorised. This process is called departmental planning which falls under plant layout operation.

There are four categories to which the product manufactured can be assigned as listed in (Tompkins, 2003). The first category is referred to as a production line department. In this department the product being manufactured is highly standardized. The layout of the factory must be designed in such a manner as to support the manufacturing process by combining all the workstations needed to produce the product.

When the product is very large and difficult to move, it will be classified as a fixed materials locations department. Another feature of this department is infrequent demand for the product. For this type of department the workstations will ideally be located at the site where the product is manufactured.

When demand and variety of the product is medium the planning department is called a product family department. Due to the similarity of the components the workstations are grouped together to perform the needed tasks. The vessels Clyde Bergemann Africa is looking to manufacture in house are of medium demand and variety. Thus this product planning department will be considered.

When the workstations are combined in such a manner as to combine similar activities to the same department it is called the process planning department. This department is mostly used in facilities where the variety of the product is high but the demand is low.

For the different product planning departments there is an associated facility layout. The department together with the associated layout as listed in Tompkins 2003 are listed below:

- Product planning department – Product line layout
- Product family planning department – Group technology layout
- Fixed materials planning department – Fixed material location layout
- Process planning department – Process layout

The optimal layout strategy for Clyde Bergemann Africa is a combination of product line layout and process layout. The flow of the product being manufactured is indicative of a production line layout. This is because the materials and partly completed equipment flows from one workstation to the next. The workstations are not located in such a manner as to facilitate straight line flow throughout the facility. The material may flow back to a workstation at the beginning of the process. This aspect of the flow through the facility is the reason for the combination of the different layout types. There may be workstations that is planned in such a manner as to facilitate the completion of a certain part of the manufacturing process within the one station due to the size of the equipment being produced. This is another reason for the need to combine the different layouts.

5.1.5 Different layout procedures

Whether the process of designing the layout of a facility is of the construction type or improvement type there are a number of methods available to achieve the best results. The following procedures will be discussed in the document:

- Reed's Layout
- Nadler's Layout Planning
- CORELAP (**Co**mputerized **Re**lationship **La**yout **P**lanning) by Lee and Moore
- Apple's Plant Layout Procedure
- Systematic Layout Planning by Muther

5.1.5.1 Reed's Layout

Advances were made in the facility planning field in the early 1960's when Reed developed a 'layout planning chart'. This chart was a great leap forward because it integrated a large number of factors which must be considered when designing a facility. These factors included the flow process, standard time for each operation, machine selection, manpower selection and materials handling requirement, as noted in Gopalakrishnan et al (2004: 200).

The following steps are a summation of the steps to follow when using Reed's layout plan as listed in Tompkins (2003: 304):

1. Analyze the product to be produced
2. Determine the needed processes for the production of the product
3. Compile layout planning charts
4. Determine workstations
5. Analyze 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 future expansion

5.1.5.2 Nadler's layout planning

Only a few years passed before the next leap forward was made. Nadler proposed an ideal system approach to material handling and facility layout. When using Nadler's approach you first find the 'theoretically best' option followed by 'ultimate' ideal system and so forth. The figure below illustrates the sequence to follow (Grassie 2008: 11):

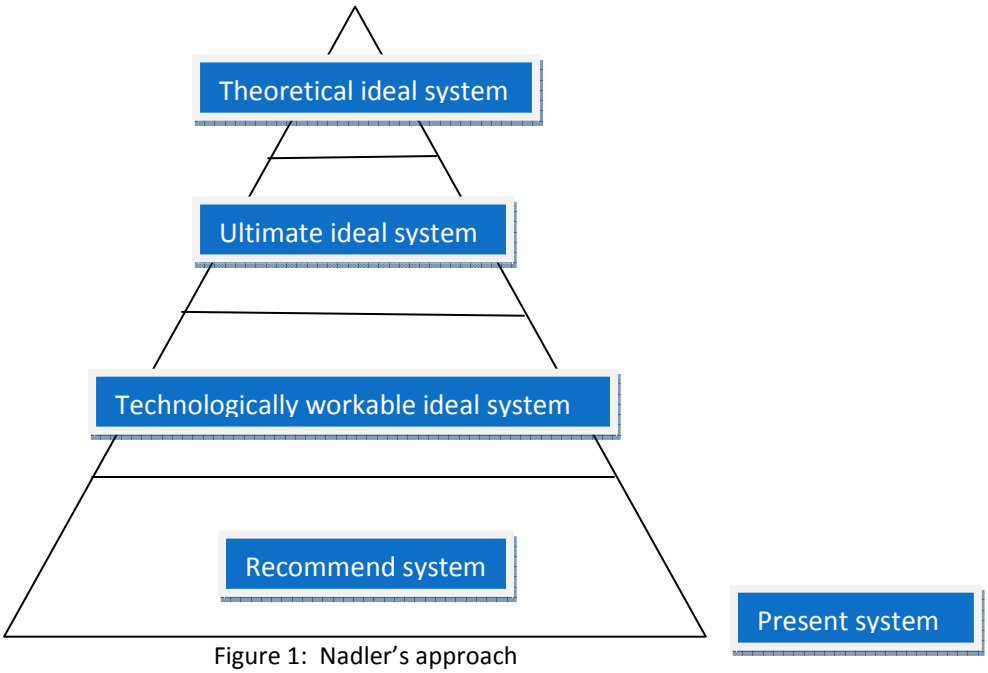

Figure 1: Nadler's approach

5.1.5.3 CORELAP by Lee and Moore

CORELAP is a heuristic model which was developed by Lee and Moore in 1967. The most important factor when using this model is the Total Closeness Ratio (TCR). A layout for the facility is constructed by this model by calculating the TCR for each department (Gopalakrishnan 2004: 200). To calculate the Total Closeness Ratio a numerical value is assigned to the closeness relationship between departments. The sum of these values is the TCR.

5.1.5.4 Apple's Plant Layout Procedure

Apple gave a very detailed sequence of steps to design the layout for a facility. This is the only procedure where the sequence of the steps is not that important, as stated by Apple. The 20 steps include:

1. Procure the basic data
2. Analyze 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 approvals
19. Install the layout
20. Follow up on implementation of the layout

5.1.5.5 Systematic Layout Planning by Muther

The Systematic Layout Planning (SLP) is the most popular and widely used planning procedure. It was developed in 1973 by Muther. This procedure can be divided into two parts. When part one is completed a block layout of the facility is generated. The second part gives a detailed layout for each planning department. The information needed to complete part two includes workstations, entrances to and exits from the departments, relationships between machines and storage locations.

Although this is the most used procedure there are a few disadvantages. This is normally not a very complicated procedure, but difficulties can occur. Alternative relationship diagrams may be generated with the same benefits. This makes elimination of the inadequate designs more difficult. To generate alternative layouts that are feasible from the relationship diagram needs experience, intuition and judgement.

5.2 Material Handling

5.2.1 Material Handling Defined

Material handling is the flow of materials and goods in their totality through the facility, as well as the packaging and storing (Lindkvist 1985). The material handling systems within a facility represents a large and growing part of the cost, estimated to be between 15% and 70%, incurred during the planning phase. For this reason adequate data is needed to ensure the correct equipment will be used in the facility to minimize cost.

Only 10% of the time the product spends on the factory floor is for production. The remainder of the time is either waiting time or transportation time. It is thus a necessity that the material handling system operates at an optimum. An effective handling system will save a considerable amount of added time.

To reduce wastage, breakage, loss, scraps, etc. proper and careful handling of the material is needed. This is achieved by using the correct handling system at the correct places within the facility. When the handling system is functioning effectively and efficiently there is a reduction in congestion, timely delivery of parts and assemblies and idle time of the workforce (van Antwerpen 2008: 9).

5.2.2 The appropriate handling system

The production process can be divided into two sections namely manufacturing and assembly. The new facility commissioned by Clyde Bergemann Africa is a combination of these two sections. Lindkvist (1985: 24) states that in manufacture the handling system is secondary to the other factors such as the material labour and machinery which is the primary factor in the design. In assembly the material handling system is the important factor to consider.

The table below gives a few examples of the different handling equipment that can be used for assembly operations (Lindkvist 1985: 24):

Internal Handling Equipment	Line Assembly	Group Assembly
Roller Conveyors	X	
Belt Conveyors	X	
Chain Conveyors	X	
Slat Conveyors	X	
Overhead travelling Cranes	X	X
Telpher Systems	X	X
Auto Guided Vehicles	X	X
Air-cushion Systems		X

Table 1: Examples of internal handling equipment of assembly operations

5.3 Methods and Standards Study

5.3.1 Methods and Standards Scope

After the facility layout has been completed, the next step in this project is to determine the processes needed during the manufacturing of the product as well as standardizing of the methods. The aforementioned is done by methods engineering. Methods engineering consist of more than just determining the best way to do the work on hand. It includes the designing, creating and selecting the best manufacturing methods, processes, tools, equipment, and skills to manufacture the product (Niebel et al 2004: 4).

When designing a new workstation method engineers use a systematic approach as described by Niebel et al (2004). The steps followed in this procedure are:

1. Select the project
2. Collect and process data
3. Analyze the data
4. Determine the ideal method
5. Present and install method
6. Develop a job analysis
7. Establish time standards
8. Follow up the method

When these steps have been completed the work is done in less time as well as much easier in terms of the employees' health and safety (Niebel etal 2004).

5.3.2 Why is standardizing needed?

The main objectives of the methods, standards and work design are to improve productivity in a facility and ensure a safe workplace for the employees. When an effective and efficient workstation has been design and implemented, an increase in the productivity of the facility is inevitable. Productivity is defined as the ratio of input versus output. When a production process has a high productivity rate a great deal of output is produced from the resources available.

Safety in the workplace is better known as ergonomics. Ergonomics focuses on the part of the workers in the facility, the design of equipment to ensure safe use and creating a comfortable and safe environment. Ergonomics can be place within different processes in a company. Its functions and effectiveness is determined by its location in the company. As stated by Salvendy (1997) ergonomics can be part of either product design, processes, manufacturing or personnel.

When ergonomics forms part of product design the goal is to make the product more user-friendly to ensure customer satisfaction. Ergonomics in processes focuses on designing a safe and effective process to protect the workers from harm. In manufacturing the ergonomist is concerned with increase productivity, profitability and quality. Finally, ergonomics as a part of personnel focuses on the health and safety of the workforce.

Karwowski (1998: 3) gave the following elements for ergonomics contributions in a facility:

- Job design
- Workplace design

The above mentioned facts can all be achieved with method, standard and work design.

5.4 Simulation

5.4.1 Simulation and facility design combined

Simulation is the action of mimicking the behaviour of real systems with the help of a broad collection of methods. The simulation is usually done on a computer equipped with the correct software (Kelton et al 2004).

Simulation is used to evaluate a newly designed of redesign facility layout in which randomness of events exists (Gopalakrishnan 2004). In this context simulation is used as a stochastic model. The behaviour of a manufacturing process can be predicted by the use of a simulation model. The model determines the movement and interaction of the different departments in the system. For this reason simulation is a valuable tool when designing a facility. It helps to evaluate the alternative generated and study the flexibility of the facility. Simulation is also used to answer questions about capacity and staffing (Piplani et al 2004).

The list below illustrates only a few of the wide variety of applications of simulation (Reinders 2008):

- Work Flow planning
- Capacity planning
- Throughput analysis
- Layout analysis
- Production scheduling
- Bottleneck analysis
- Productivity improvements
- Cycle time reduction

Problems are generally experience in the start-up of a new or redesigned facility. These pitfalls can be avoided when the facility with the new layout and processes are first simulated and the resulting model studied and analyzed. This can also reduce the cost which is incurred when bottle necks and problem areas must be corrected.

Reinders (2008) give the following characteristics of simulation that makes it such a powerful planning and decision-making tool:

- Is versatile enough to model any system
- Provides results that are easy to understand and communicate
- Captures system interdependencies
- Shows behaviour over time
- Runs in compressed, real, or even delayed time
- Is visually appealing and engages people's interest
- Provides results that are easy to understand and communicate

As with everything in life the simulation approach to problem solving is not perfect. There are a number of problems that must be considered. The systems in a facility is usually rather complex. Writing the computer programme to simulate the processes can be an arduous task. The more complex the system, the more computer time is needed to complete the simulation. These extended computer runs can delay the project's progress. Finally, simulation is often seen by many as just a computer exercise. The result is that the model is only run a few times with the result not studied properly. The 'answer' which is gained is going to be an inferior one (Law et al 1982).

5.4.2 When is simulation fitting?

Although simulation is a great help to solve a number of problems, it can't solve all the problems which arise when designing a facility. The correct tool must be identified to solve certain problems. To determine whether simulation is the correct tool the following questions must be answered. Is the cost of simulation less than the cost to experiment on the actual system? Will the cost implications of doing the simulation outweigh that of the decision? Is an operational decision being made? When the answers to the above mentioned questions are yes, then simulation is the right course of action.

With the help of simulation the optimal facility layout can be determined for Clyde Bergemann Africa.

6. Methods, Tools and Techniques

6.1 Facilities Planning

Facility planning is a continuous process that needs constant evaluation to determine whether the current facility lines up with the objectives. The facilities planning cycle can be used when planning a new facility of re-planning the existing one. The cycle is illustrated in the figure below:

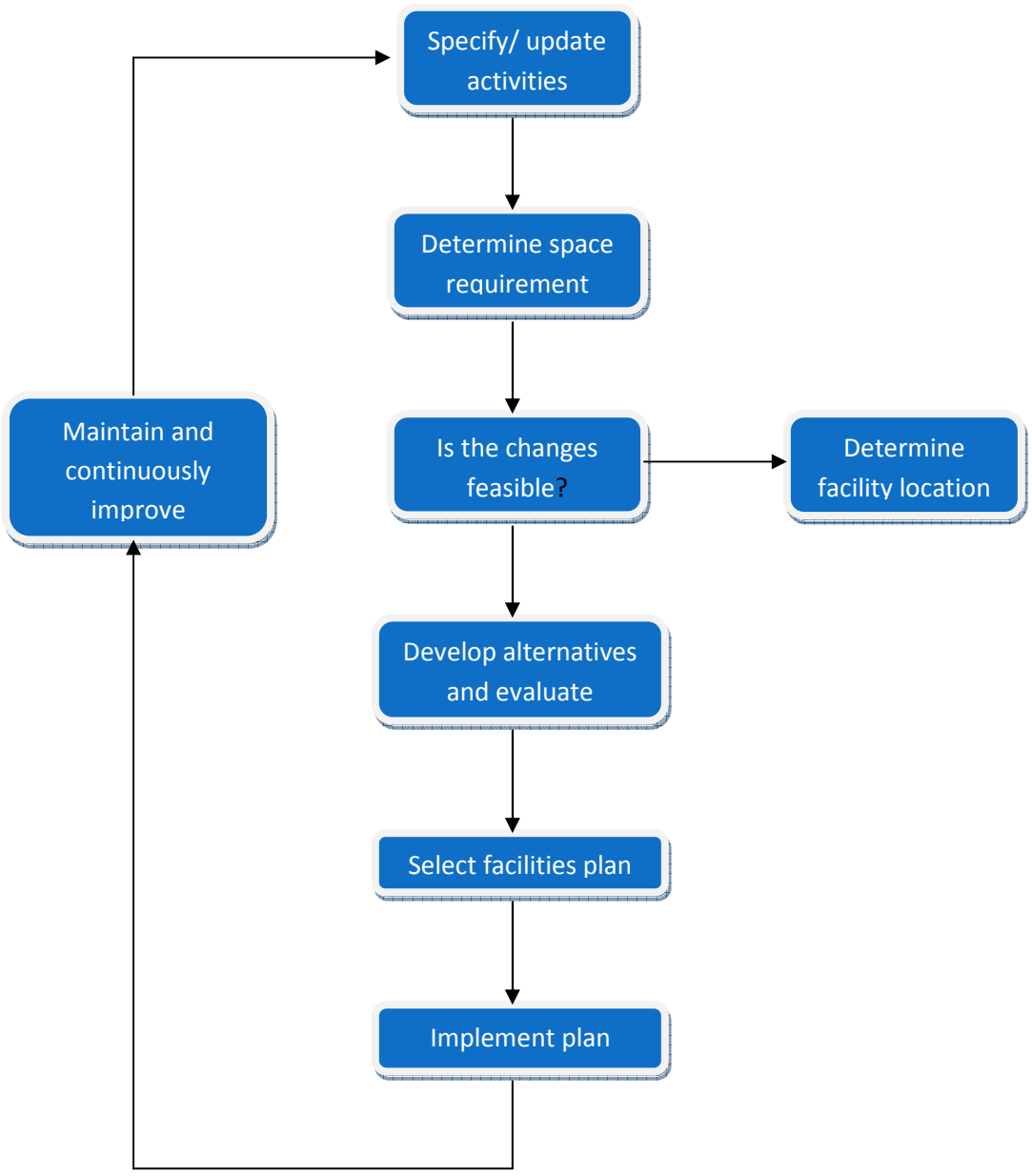

Figure 2: Facility planning cycle

Tompkins et al (2004) lists the procedure to be followed when designing a facility. Within these steps certain tools and techniques will be used to deliver the required results.

- Define the problems
  - State the objectives of the facility
  - Specify all the activities to be performed in the manufacturing process
- Analyze the problem
  - Establish the relationships between the activities
- Determine the space requirements
  - Generate different alternatives
- Evaluate the alternatives
- Select the preferred alternative
- Implement the design
  - Maintain new design and continuously improve
  - Redefine the company's objectives

The problem has been identified by studying the current workshop layout implemented at Clyde Bergemann Africa. Talking to the workforce, both in the office and on the floor, helped to determine what the objectives for the new facility are.

Once the first step has been completed, Muther's Systematic Layout Planning (SLP) will be used to complete the remaining steps. This method is used for its versatility. It can be used throughout different areas in both the public and private sectors. SLP assists in the layout of offices, service companies, warehouses and manufacturing businesses. The approach also doesn't change regardless if it is minor or major rearrangements to an existing facility or the planning of a brand new facility.

Within Muther's Systematic Layout Planning there are four phases that should be followed. These phases are:

- Phase 1: Location
- Phase 2: Planning of the general overall layout
- Phase 3: Preparation of detailed layout plans
- Phase 4: Installation

Phase 2 establishes the flow pattern(s) of the new workshop. The relationships between the different departments, the size as well as their configuration are also addressed in phase 2. The detailed layout plans includes where each piece of equipment will be placed. Phase 1 and 4 are not covered in this project (Maynard 1971). These four phases are depicted in the figure below (Tompkins 2004).

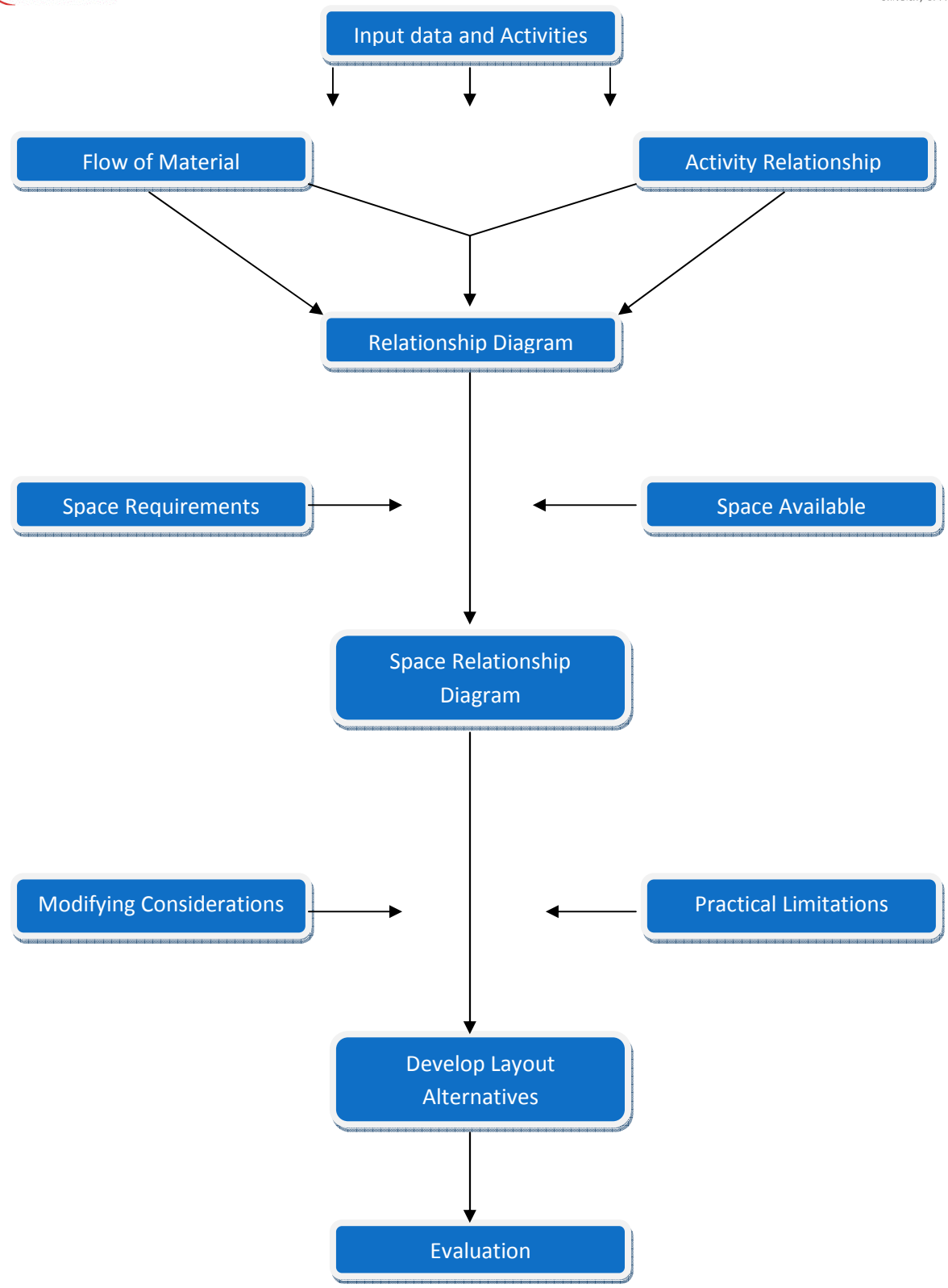

Figure 3: Graphic illustration of the SLP process

The techniques and tools used to complete the phases mentioned above starts with the flow of material throughout the workshop. The results are recorded on the operation process chart. The flow of material and the activities present in the workshop are combined to produce the activity relationship diagram. To complete the relationship diagram information must be gathered about the process equipment and machinery necessary. The relationship diagram is an illustration of the geographical location of the departments without taking space requirements into account.

An Activities area and features sheet is constructed to determine the space required per department. The needed space per department combined with the relationship diagram results in the space relationship diagram. This diagram is then used to construct a number of alternatives in block layouts. To have an effective block layout the operating practices, aisles and safety must be incorporated.

When the material handling is taken into account as well as the location of all the equipment and machinery, a detailed layout will be completed.

6.2 Methods, standards and work design

To ensure that the workshop functions productively and complies with the Health and Safety Act of South Africa, all the tasks preformed in each department will be standardized. This will be done by time studies to determine the allowable time to perform certain tasks as well as looking at the ergonomics of the facility.

The uses of the time study data is listed below (Maynard 1973):

- Developing effective methods and plans in advance of beginning production
- Improving existing methods
- Establishing time standards
- Developing time formulas for standard data
- Cost estimating
- Aiding product designs
- Developing effective tool designs
- Selecting effective equipment
- Training supervisors to become methods-conscious
- Settling time study and wage rate grievances
- Operator training
- Research in such subjects as operating methods, training, and performance rating

The main objective of the time study of the project is to establish time standards, develop effective methods for the new production line as well as improving existing methods.

There are a number of time study methods including the stopwatch method and the motion picture method. The stopwatch method will be utilized in this project. Due to the fact that the opportunity exists to only make a study of the processes currently performed at CBZ, predetermined time standards will be used.

6.3 Simulation

The simulation of the facility is the final stage of the project. All the gathered information will be used to accurately depict the workshop. *Arena* is the chosen software.

7. Facility Design

7.1 Brief description of the dense vessel

The dense vessel CBZ is looking to manufacture in-house is used in the pneumatic conveying systems. It is a large piece of equipment with dimensions of 3.8m in height and 1.5m diameter. This piece of equipment consists of four parts namely the dome, the body, the conical section and, the pipe and steel work, as illustrated in the figure blow.

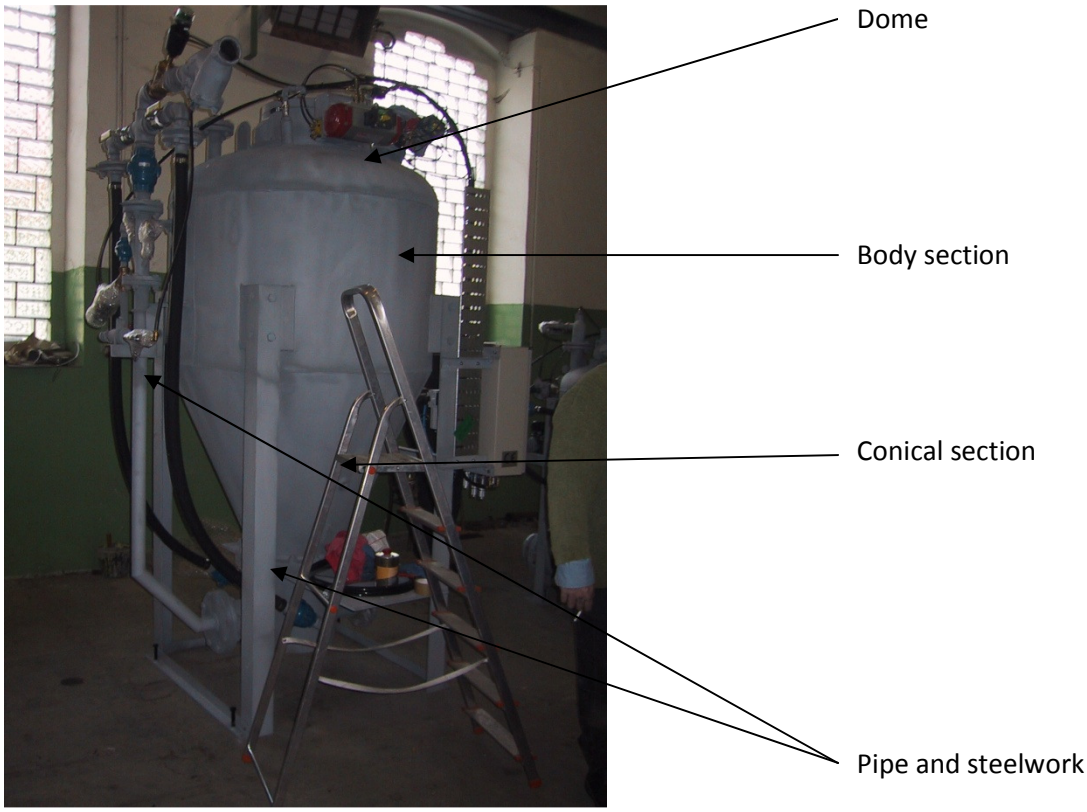

Figure 4: Dense vessel

The body and cone sections will be manufactured from beginning to end in the facility. The dome section will be imported due to the complexity of manufacturing. The pipe and steelwork will be cut to the correct size and welded to the vessel.

There is a dome valve at the top and bottom of the vessel. The dome valves monitor the amount of the material that enters and leaves the vessel. The dome valves will be assembled in the facility with all the needed parts to be imported. This process falls under the jurisdiction of the operations section of CBZ and therefore the detailed description of how the valves are assemble as well as a time study for the given part will not be discussed in this project.

The entire vessel is controlled by the control panel. This panel is also imported.

7.2 Identifying the different departments

The manufacturing process of the dense vessels consists of a number of departments. Within each of these departments one of more specific manufacturing process(es) will be preformed. The following departments will be needed to manufacture and assemble the dense vessels:

- Department 1 – Rolling and forming
- Department 2 – Pipe and Steelwork
- Department 3 – Pre-manufacture
- Department 4 – Welding
- Department 5 – Testing
- Department 6 – Manufacturing
- Department 7 – Assembly
- Department 8 – Sandblasting
- Department 9 – Paint
- Department 10 – Packing and loading

Department 1 - Rolling and forming: This department receives the material, sheet metal, from the suppliers. Once the material has been off loaded and inspected to ensure the specifications are met, it moves into the production line.

In department 1 the material is cut and rolled into the needed shapes to correctly assemble the vessel namely the body and conical sections.

Department 2 – Pipe and steelwork: This is the first department that will function in parallel with the manufacturing process. In this department the legs of the vessel will be cut to the correct size. The pipe work will also commence in this department by cutting the pipes to the correct sizes. Once this process has been completed the steel work is sent to department 3, Pre-manufacture, where it will be prepared for the welding process. The pipe work is moves to department 7.

Department 3 – Pre-manufacture: In this department all the needed preparations will be done before the rolled plates can move onto the welding department. This includes insuring that the welding surfaces are clean are ready to be welded. The body and cone sections will be individually tag welded. A Final FIT-UP must be completed before the tagged sections can be moved forward to ensure that there are no irregularities.

Department 4 – Welding: In this department the vessel starts to take shape. The body section is individually welded together with a root, filler and a cap. Once this has been completed the 3 sections (dome, body and cone) are welded together with the same process with which the individual sections were welded. The legs of the vessel are also welded to the structure.

Once the vessel has been welded together, the manholes are cut into the vessel before the top and bottom flanges can be welded onto the vessel. The preparations are also done for the pipe work. The final stage in this department is to prepare the vessel for the testing process.

Department 5 – Testing: This department, as all the others, consists of a number of processes. The newly assembled vessel must be x-rayed to ensure that there are no defects. Since pneumatic conveying functions with high pressured air, the system will not work properly it any defects are present. If there are any defects detected the repairs are done within this department.

When the vessel is completely assembled it must undergo a high pressure test to ensure that all the specifications are met and that the vessel functions properly. A third party is present when the final test and inspections are preformed.

Department 6 – Manufacturing: This department will mainly be used for the manufacturing of the sootblowers and is thus not discussed in this report.

Department 7 – Assembly: In this department all the different components are assembled into the final vessel. This includes the welded body of the vessel, the dome valves and the pipe work.

Departments 8, 9 and 10 – Sandblasting, painting, and loading and packing: After all the needed tests have been completed, the vessel must be sandblasted and painted. This must take place outside the facility to prevent health hazards.

Because of the size of these vessels, specialized packaging must be used. Clyde Bergemann Africa will make use of a transportation company to deliver the vessels to the client. The vessels will not be kept in inventory very long. As soon as the capacity of the transportation vehicle has been reach, the vessels will be delivered.

How the material flow from department to department is illustrated in the flow process chart in Appendix A

7.3 The flow of material through the facility

7.3.1 Planning department classification

When designing a facility, there are three important factors to consider namely flow, space and activity relationships. In this section of the report a study was made of the flow through the facility. According to Tompkins et al (2003) flow depends on more the just the way the material moves through the facility. Lot size, unit load sizes, material handling equipment, layout arrangement, and building configuration all play a vital role.

Before the flow pattern needed in the facility can be identified, the type of planning department systems must be discussed. Production, service areas, administrative and support all form part of the planning departments. There are four different planning departments that may be applicable to CBZ's new facility.

To determine which planning department will fit Clyde Bergemann's facility most effectively, the variety and volume of the product to be manufactured was studied. The dense vessels are of medium volume and medium variety and thus the product family planning department is best suited to the facility. Group technology layout goes hand-in-hand with this planning department.

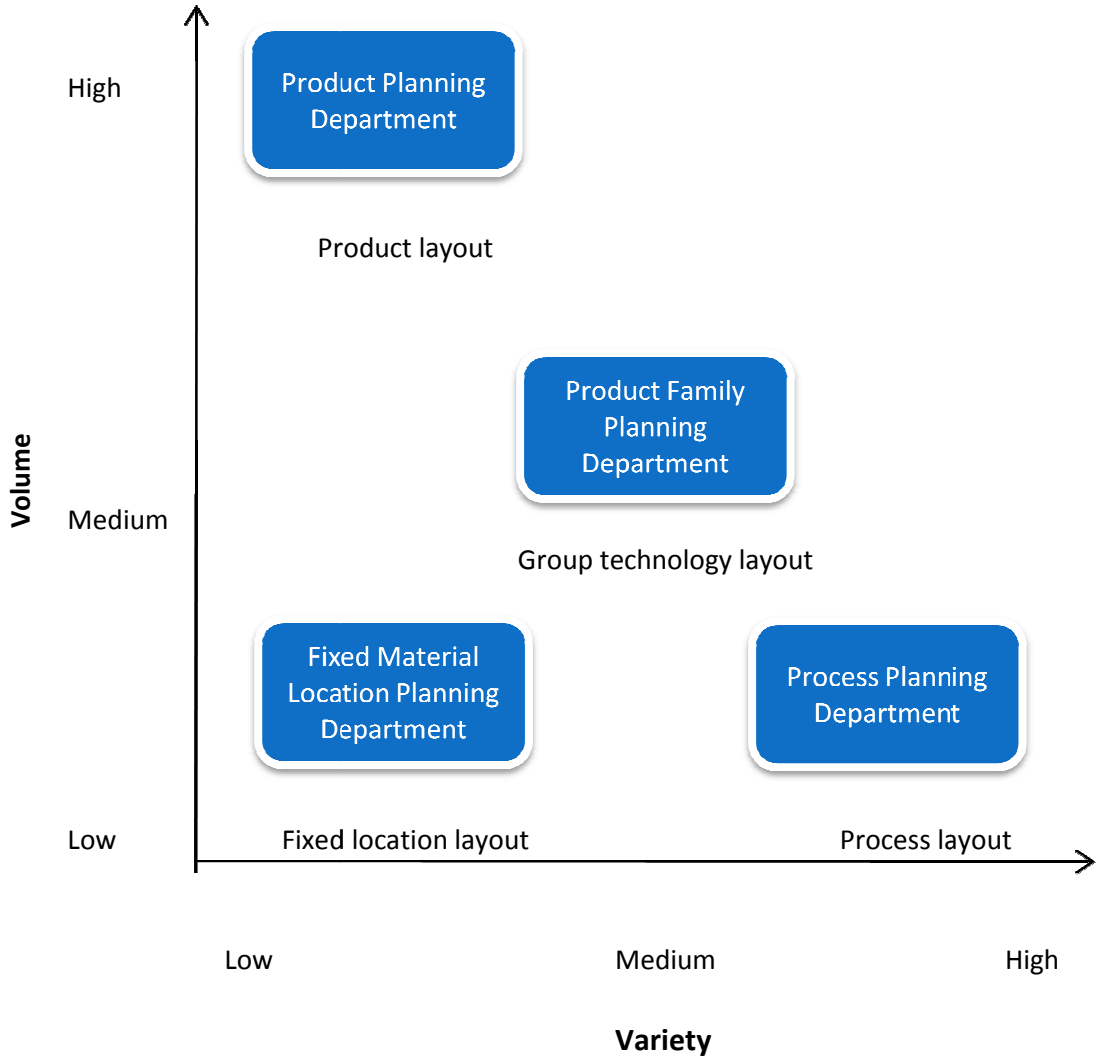

Figure 5: Volume variety layout classification as illustrated in Tompkins et al 2003

As anything in life, the planning departments are not without complications. Although most of the characteristics of the product family planning department comply with CBZ's facility, there is an overlap of characteristics with another planning department.

The process planning department also describes some of the aspects present within this facility. Some of the departments contain similar processes. This results in the flow through the facility as a combination of group technology layout and process layout.

7.3.2 Flow pattern within the departments

Now that the planning department has been determined, the flow within the departments can be studied. As the planning department for the facility was identified as both product and product family departments, the flow of work follows the product flow specification. There are a number of different patterns within this field namely

- End-to-end
- Back-to-back
- Front-to-front
- Circular
- Odd-angle

The main pattern within the facility is the end-to-end. This pattern is illustrated below. The restrictions existing in the building results in the flow pattern deviating slightly from the standards present in the end-to-end configuration. The back and forth movement of the vessel between the different departments also has an effect on the flow pattern.

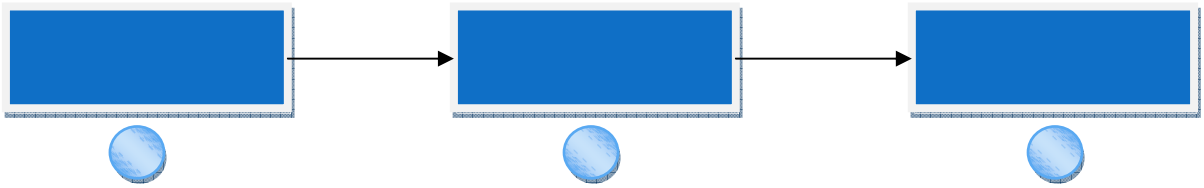

Figure 6: End-to-end flow pattern

7.3.3 Flow between departments

To determine the flow between departments the location of the entrance and exits is of critical importance. This location is fixed for the given facility and thus the flow through the facility must conform to the restriction. For the facility Clyde Bergemann will be using there exists one receiving area but two dispatch areas. Therefore the flow through the facility is a compromise of a few available patterns as shown below.

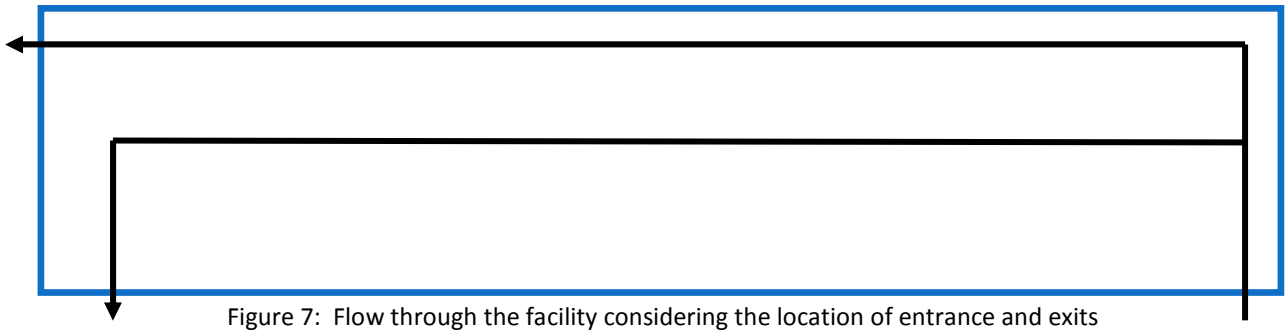

Figure 7: Flow through the facility considering the location of entrance and exits

Figures 8 and 9: The receiving and dispatching doors

Figure 10: The exit on the side of the building

Interaction between departments was recorded on the operation process chart shown in Appendix C. This chart doesn't depict the specifics of the process, but rather a more general

flow. This was used to get a better understanding of how the parts and material should flow through the facility.

The information gathered from the operation process chart assisted in constructing the relationship diagram. This diagram places the different departments spatially towards each other. Space requirements have not yet been assigned to the departments. The relationship diagram is used to graphically illustrate the movement of the material on the factory floor and thus establish the critical path through the facility.

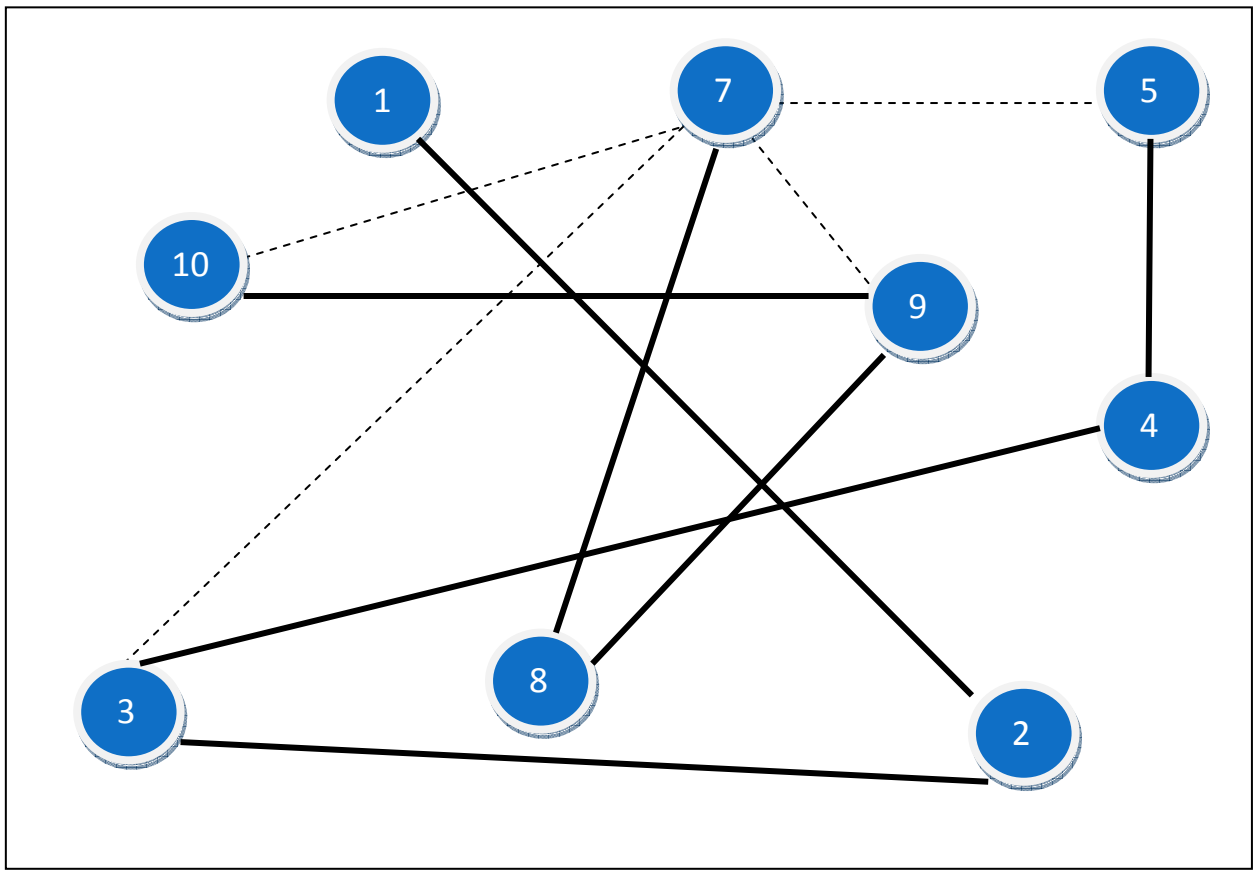

Figure 11: Relationship diagram

The flow of material between the different departments is graphically illustrated in Appendix B. The process flow of the facility was constructed with the help of *Bizagi Studio*.

7.4 Department specification

Once the flow between the different departments as well as through the facility was studied and recorded, the next step was to determine the departmental service requirements.

In this section the space required per department can be approximated by establishing the equipment that will be present in the department, the space needed for material handling

within the department as well as the operator requirements. This data gathered was recorded on the departmental service and area requirements sheet, see Appendix D.

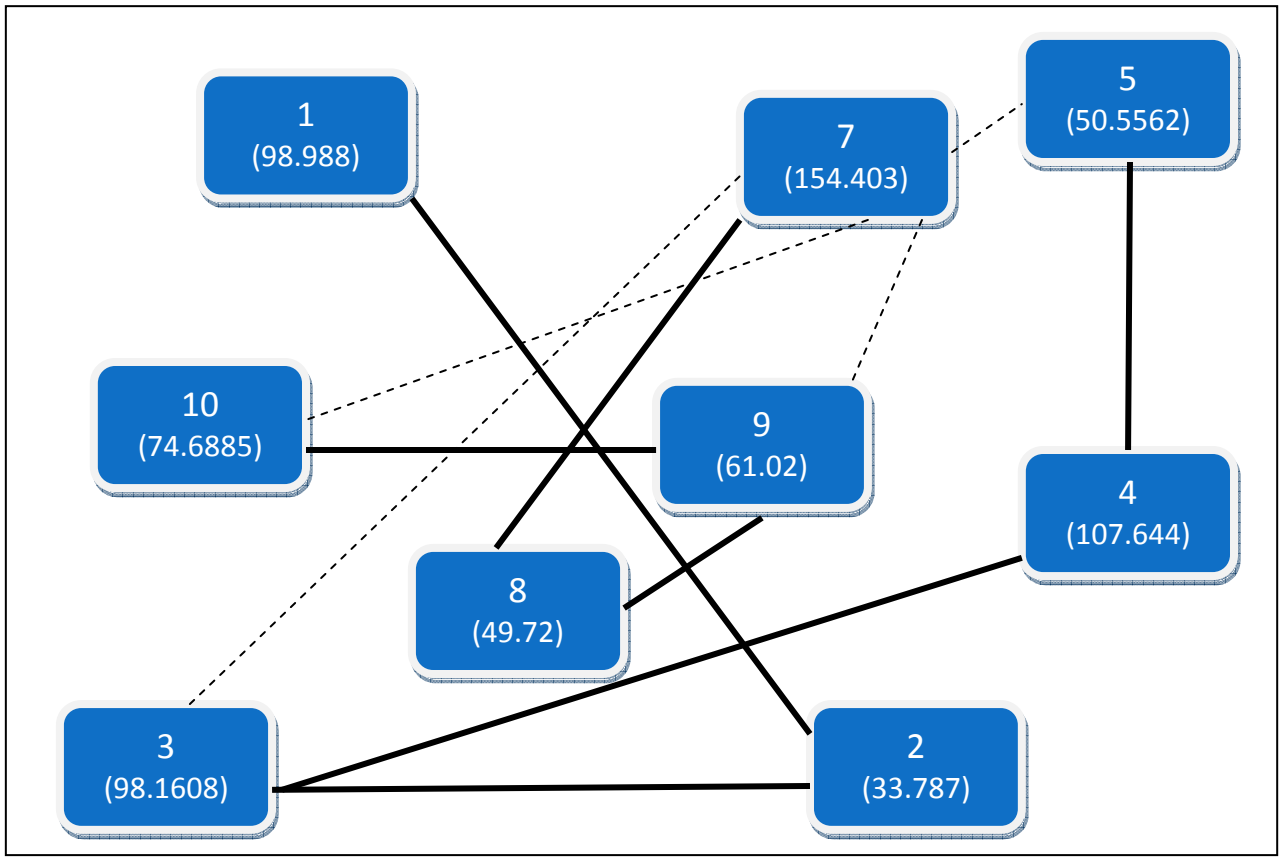

Figure 12: Space relationship diagram

The above diagram is an illustration of the flow between departments as well as the space required by each department. This diagram is a summary of the departmental service and area requirement sheet and the relationship diagram.

7.5 Alternative layouts

The final step in the completion of the facility layout for CBZ was to combine the above mentioned information and charts into possible block layouts. It was important the take the limitations of the facility and surrounding grounds into account otherwise this oversight can have crippling effects on the proposed layout.

These limitations include the structure of the building. Within the building there is steel support structures space every 5 m as shown in the figure below.

Figure 13: Structural restrictions

These structures had a great influence in the manner the layout process was approached. The placement of each department in the facility was considered for

- Firstly, the equipment used in each department and whether the limitations will hamper the effective and efficient operation of the equipment.
- And secondly, the material that needs to be handled within the different departments as well as transported between the departments.

The other factors that were taken into account were the entrance and exist, as discussed earlier. The location of the power points in the facility played a decisive role in the placing of the equipment within the departments.

The alternative that were generated and evaluated for their plausibility are illustrated and discussed below:

7.5.1 Option 1

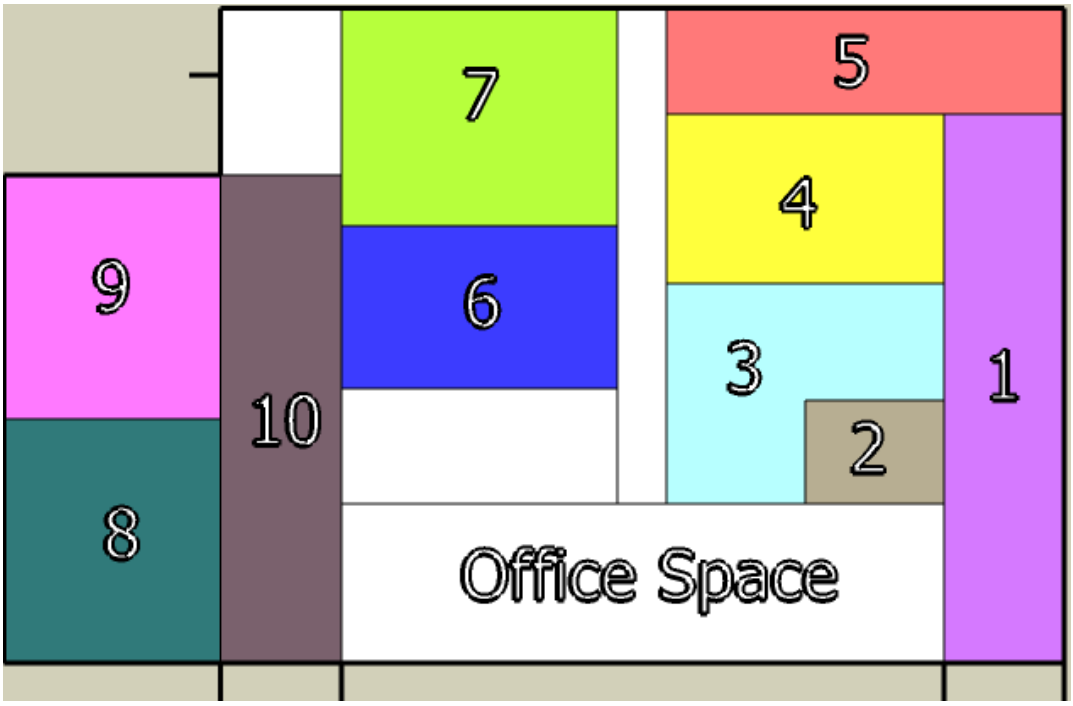

Figure 14: Layout alternative 1

This is one of the proposed layouts that will solve the facility layout problem CBZ currently has. The two white areas are reserved for future ventures such as manufacturing soot blowers and a quarantine store. The processes of departments 9 and 8 have to be conducted outside to ensure that there are no transgressions of the Health and Safety Act of South Africa.

Departments 1 and 10 are ideally located to make the receiving of material as well as the dispatch of the finished products as efficient as possible. Department 10 is situated at the side of the facility that has the two exits. This will create the opportunity to use one of the exits for the dense vessels and the other for the soot blowers, which is a future venture the company wants to pursue. The other departments are arranged in a specific order to improve the workflow in the facility.

The test and inspection area, department 5, is located at the back of the facility for safety reasons. When the vessels are placed under pressure to examine the welding and if a defect is present, the possibility exists that a member of the workforce may be injured. For this reason department 5 is not place near the walkway or the office space.

Department 7, the assemble area, is situated near one of the exit to make the movement of the completed assembled vessel to the sandblasting and painting departments more effective and less dangerous. The machining department is positioned in such a manner that it can be used by both the dense vessel assembly (if needed) and soot blowers manufacturing processes.

The close proximity of the assembly department and the machining department is also an attempt to reduce the transport time. Departments three and four are closely located for the same reason.

When the final test and inspection has been completed, the vessels must once again be transported to the assembly area. The reason for this is that the pipe work must be removed before the vessel can be packed and despatched to the client. This will help prevent any possible damage to the pipe work during transportation.

Possible problems with this alternative:

- There is a double movement when the vessels is transported to the sandblasting and painting areas
- Moving the rolled plates to the next department may result in a double movement
- A number of departments must be crossed to test the completed soot blowers
- Department 2 is isolated from the machining department

7.5.2 Option 2

The second option illustrated below has the same overall feeling as alternative one with departments 1, 2, 3, 4 and 5 on one side of the walkway and the remainder of departments on the other side. Departments 8 and 9 are again place outside the facility for health and safety reasons. The placement of each department is different however.

The 'receive and despatch' areas in the facility is located near an exit to make the movement of material and vessels more effective. In this layout department 7 is situated at the bottom end of the facility. This improves the transportation of the assembled vessels to the sandblasting and painting area.

In this layout, departments 3 and 4 remain closely situated. This ensures that there is no unneeded movement between the departments. The same principle applies to departments 1, 2 and 3. The machining department remains accessible to both production lines. For safety reasons department 5 is once again located at the back of the facility, away from the walkway and the office space.

Possible problems with this alternative:

- The assembled vessels must undergo a final test and inspection before it can be transported to the client. In this layout the vessels must cross a number of departments to reach the test and inspection area
- With this layout the two possible exits are reduced to one. This will result in both the dense vessels and soot blowers being despatch from only one exit
- There is no distinct separation between the two different manufacturing processes
- Transporting the welded vessel to the assembly area in not ideal. A significantly heavy part must be transported over a number of departments which is a risky undertaking
- Department 2 is isolated from the machining department

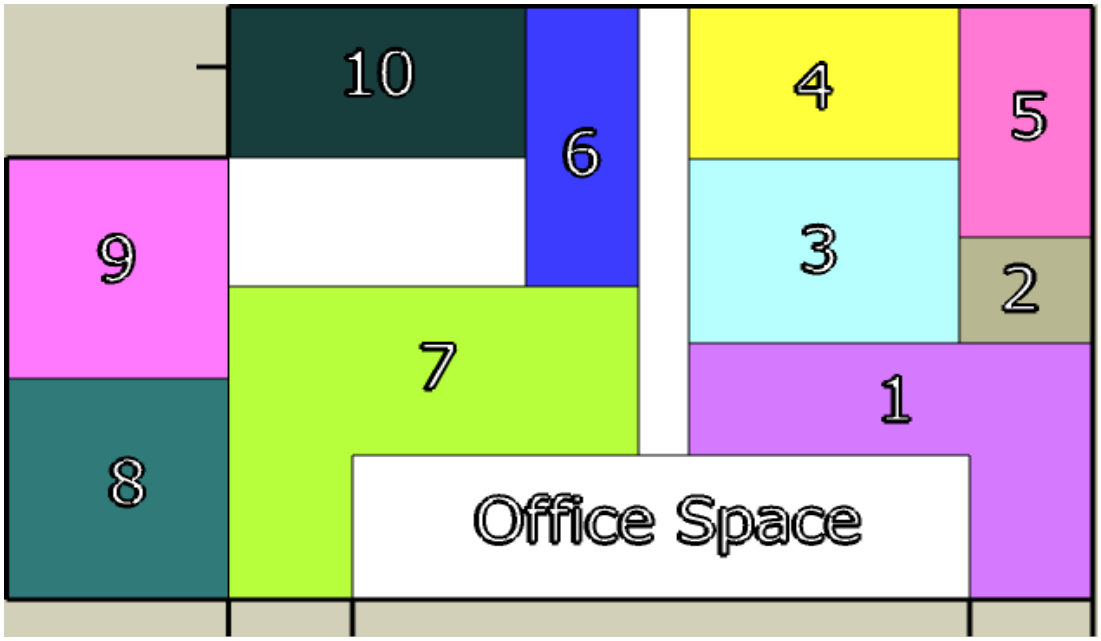

Figure 15: Alternative layout number two

7.5.3 Option 3

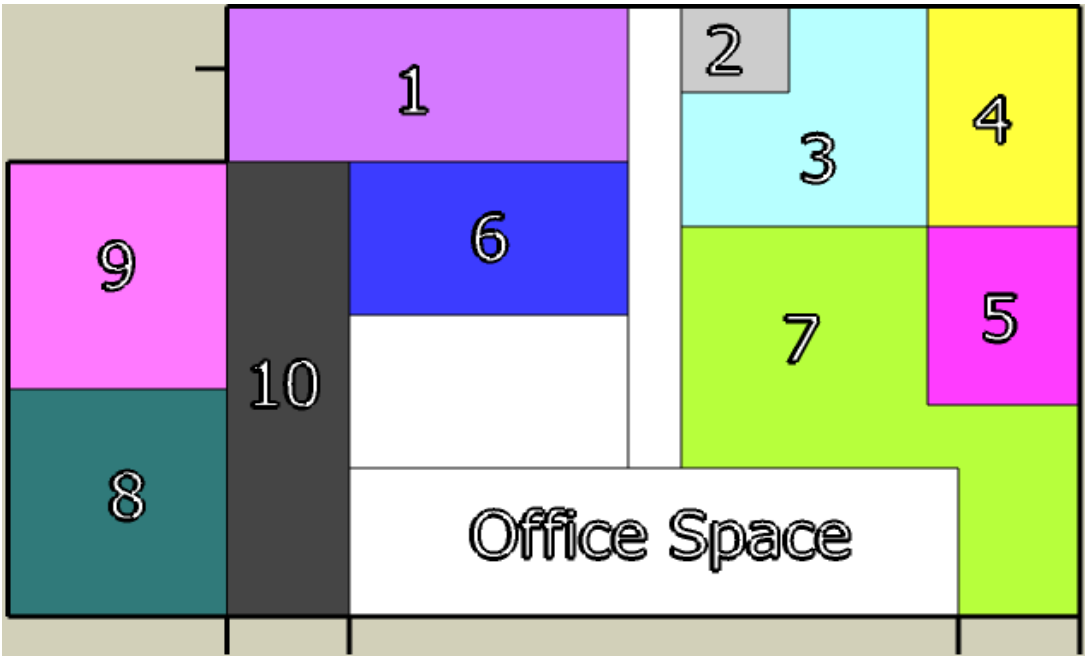

Figure 16: Alternative layout 3

With this layout the flow between departments is in the u-shape configuration. This makes it difficult to accommodated two manufacturing processes within one facility. But since the soot blowers are only a future venture, this possible layout has been suggested and evaluated.

For this layout option the receiving area is located at the side entrance. The packing and despatch area is situated at the same location as option one. There is a continuous flow of material from receiving to test and inspection. The test and inspection department is closely located to the assembly area to reduce travelling time for the assembled vessel to the final test and inspection.

Department 2 is more closely located to the machining department which will benefit the soot blower manufacturing process.

Department 8 and 9 are situated outside the facility to ensure that CBZ complies with the health and safety act of South Africa.

Possible problems with this alternative:

- Due to the location of department 7 at the opposite end of the facility than the sandblasting and painting areas, transporting the vessels becomes a nearly impossible task
- Moving the assembled vessel to department 10 for packing and dispatch involves moving it over a number of departments
- The future venture will experience difficulty in reaching the welding department

After much deliberation the first option was chosen. There were some minor adjustments made. Departments 2 and 3 will share the same floor space, but will still be seen as two different departments. A detailed layout of the facility is shown in Appendix E.

7.6 Material handling

7.6.1 Objectives and scope for the material handling system

As stated in Tompkins (2003), the material handling system plays a vital role in the functioning of a manufacturing process. This system accounts for 25% of the employees, 55% of the facility space and 87% of the total production time. Ensuring that the facility is equipped with the correct material handling system is critical to its success.

The scope for the material handling system which will be implemented at Clyde Bergemann Africa is the following:

The material handling system must be able to deliver the right part in the right orientation to the right department at the right time.

The objectives of the system are:

- To improve the productivity of the manufacturing process by using the best material handling system for the facility
- Reduce the handling of the different parts and components to improve productivity and striving for efficient manufacturing flow
- To install the correct system for this facility to improve and control material flow
- Improve the safety of the workers in the facility

7.6.2 The material handling system

The first step in generating alternative material handling system is to determine the type of system that will be effective in transporting the manufactured product, in this report the dense vessels. This was achieved by using the material handling system equation. The basic principle of the equation is illustrated in the figure below (Tompkins, 2003):

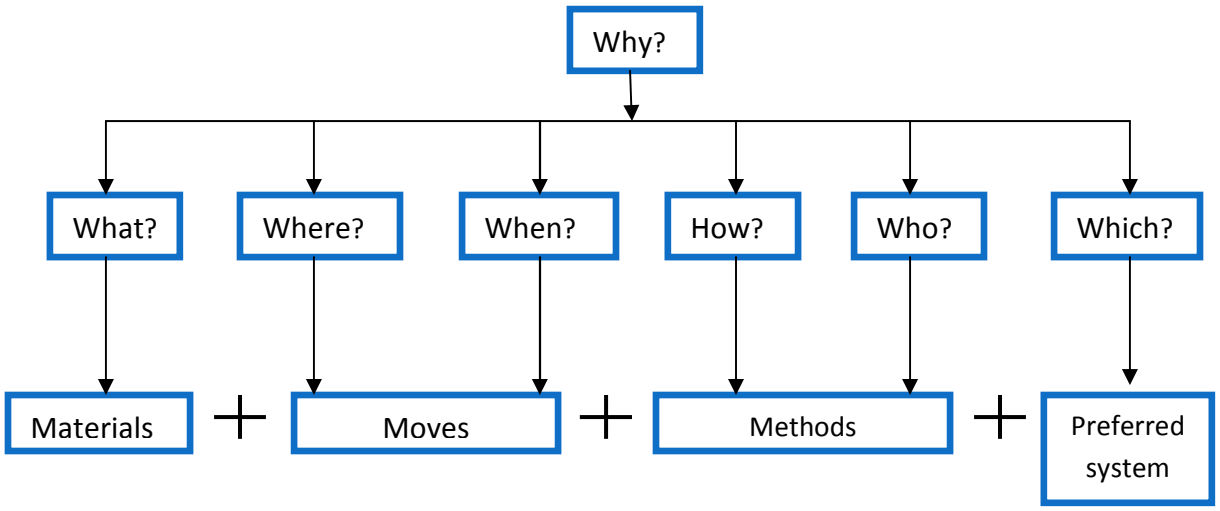

Figure 17: Material handling system equation

The answer to the 'what?' question is the material and components that will be moved from department to department. 'Where?' and 'when?' specifies the time and place requirements for the facility. The material handling methods that will be most appropriate for the system will be identified with the 'how?' and 'who?'. The answers of the above mentioned questions will lead to the recommended system.

The manufacturing process can be divided into four stages. Each of these stages has its own type of material that will move through the different departments. The different stages with the different categories of material are listed below:

- Stage one: the plates that will be rolled into the conical and body sections of the vessels as well as the pipe and steelwork
- The second stage: the rolled and conical section
- Stage three: the different sections welded together including the 'legs' of the vessel
- Stage four: completely assembled vessel

This is the material and parts that must be move throughout the facility by die material handling system.

The characteristic of the type of the material that must be moved is summarized in the table below:

Type of material	Dimensions
Plates	5m x 5m x 10mm
Pipe and steelwork	2.5 m
Conical rolled section	1.17m in height x 1.5m Ø at widest point
Dome	0.3m in height x 1.5m Ø at widest point
Rolled body section	1.43m in height x 1.5m Ø at widest point
Sections welded together	3.2m
Completely assembled vessel	3.8m in height

Table 2: Summary of the characteristics of the material

The characteristics and categories of the material that must be transported between the different departments is a determinant factor in the alternative material handling systems. It is also crucial to know where the material and parts must be collected from and where they must be delivered to within the facility. This factor has been address in the report earlier in sections 7.2 and 7.3.3.

The possibility exists that the material handling system can be over complicated by trying to implement too many different systems unified as one. As there are a number of stages in the manufacturing process, each with different material and parts, the chance is present to rather focus on the different stages instead of the manufacturing process as a whole. It must thus be kept in mind that it is optimal to minimize material handling.

Before the material handling system can be elected, the requirements of the system must be specified.

- System must be able to move heavy parts
- Must be able to handle a number of part with different geometries
- Not be constrained by the facility building
- Is special training needed for the system?
- Will structural reinforcements be needed to support the system?
- What is the system's power requirement?

The system that will best comply with the objectives of the material handling system is an overhead crane. This piece of equipment will be able to transport all the categories of material present in the facility to all the different department. A fork lift vehicle will also be utilized in the facility.

A detailed drawing illustrating the layout of the material handling system is shown in Appendix F.

8. Methods, standards and time studies

8.1 Time study defined

Methods, standards and time studies form an important part of improving productivity in the workplace. Time studies are frequently seen as determining a fair day's work (Niebel et al, 2003). A fair day's work is a very broad statement. It can be described further by stating that a fair day's work is equal to the amount of work that can be completed by a skilled worker when he/she works at a standard pace. This standard pace is determined with the help of time studies.

There is three possible ways to conduct a time study namely estimations, historical records and work measurement procedures. The estimation method relies on rather giving a guess to what the correct time standard must be than determining the time standard through observation. These standards are often more based on the judgement of the analyst than on facts. However it remains a helpful tool when there is no possibility to study a process because a facility has not yet implemented the manufacturing system.

When the historical record method is used, the time standards are based on similar processes of which the time standards have already been determined. This method is far more accurate than the estimations method. Historical records are typically used when a comparable process must be standardized. This method conveys the time it took to complete a certain task instead of how long it should actually take. Thus the most accurate way to complete time studies will be to do work measurements.

Work measurements include a number of techniques as stated in (Niebel et al, 2003). These techniques are:

- Stopwatch, electronic or mechanical time studies
- Fundamental motion data
- Standard data
- Time formulas
- Work sampling studies
- Reasonable expectancies
- Predetermined times

This method entail doing more research about the manufacturing system, including all the processes involved as well as the observation of these systems and recording the findings. By using one of the above mentioned methods to complete the time studies, the efficiency of the equipment and operator will be increased which will lead to a higher output.

In section 8.1 the different time study methods were mentioned. For this report most of the times will be reasonable expectancies due to the fact that a large number of the processes have not yet been implemented. The processes which are currently preformed at Clyde Bergemann were studied with the help of the stopwatch method.

8.2 Time study procedure

8.2.1 Operator's participation in the time study

The operator plays an important role in the time study process. Without their full co-operation the accuracy of the study will be influenced significantly and will ultimately cause the study to fail. It is thus vital that the operator be informed of the proposed study before it is conducted to ensure a positive attitude.

The operator has a number of responsibilities. When he/she fall short in completing any of these tasks, the study may be compromised. Therefore it is necessary for both the analyst as well as the factory floor supervisor to make sure that the operator is aware of these responsibilities. These tasks and responsibilities are the following:

- If new methods are studied the operator must not be bias towards the technique
- Should help identify and eliminate unwanted characteristics of the process
- Help to improve the process by making suggestions
- Assist the analyst in breaking the process down into its elements
- Complete his/her task at a steady rate
- Follow the prescribed method exactly

Using the wrong operator for the study can also have a negative effect. It can influence the accuracy of the study as well as double the difficulty of making the study. The selection of the right operator is thus crucial. The operator should be skilled worker who will apply effort into the new proposed method of completing a familiar task. In (Hodson, 1992) it is advised against using an operator whose performance deviates more that 25% from the desired 100%.

8.2.2 Share the time study findings

The main objective of the time study procedure is to collect and record informative data that will convey the most efficient and effective method to complete the required work. The time study procedure would thus be redundant if the information gather were only for the use of the analyst.

The completed study conclusions must be shared with the operator, the supervisor and the union steward. All the gathered information must be freely discussed with all parties involved and all their questions must be truly answered. This will prevent a negative attitude towards

the implementation of the new method. The results of the study should be compiled in such a manner as to enable easy use for both the supervisors, set-up personnel and the operators.

8.3 The different processes of each department

To successfully complete the calculations of the throughput time of the manufacturing line, the processes involved at each department must be fully understood and documented. A brief description has been given of the functions of the different departments in section 7.2 but not of the processes needed to produce a dense vessel. The table below gives a more structured view of the activities that will be performed throughout the facility. This table is only to demonstrate the required processes, not to indicate the processes that will run in parallel with each other.

Department	Processes	Description
Rolling and forming	• Offloading and Nibbler • Inspection and data package • Guillotine • Flame cutting • Rolling or conical rolling • Align and tack	The nibbler is used to smooth the edges of the plates Cut the plates into the cone shape before rolling commence Spot welding of the edges of the rolled plates
Pipe and steelwork	• Offload, inspect, data package • Saw • Cropping	
Pre manufacturing	• Rolled weld prep • Conical rolled weld prep • Long weld prep • Set up and tag – rolled section • Set up and tag – conical section • FIT UP	Welding that must be done on vessel that doesn't fall into the above mentioned categories Inspection before final welding can be done
Welding	• Weld rolled section • Weld conical section • Weld sections together • Steel structure welding • Manhole prep • Top and bottom flange welding • Prep for x-ray	Pipe work opening created Clean vessel before sent for x-ray

Table 3 (part 1): Processes involved in the manufacturing of the vessels

Department	Processes	Description
Testing	• Visual inspection • X-ray • Hydro pressure test	
Assembly	• Complete assembly of vessel • Assemble pipe work • Assemble steel structure • Remove pipe work from vessel	This is done to prevent damage while the vessel is transported
Sandblasting	• Sandblasting	
Paint	• 1st coat • Drying time • 2nd coat • Drying time • 3rd coat • Drying time	This is done to comply with set standard as well as the customer specifications
Packing	• Packing of vessel • Loading	

Table 3 (part 2): Processes involved in the manufacturing of the vessels

8.4 Selecting the elements

8.4.1 Definition of an element

An element is defined as a distinct part of a specific activity or task. The work done by the operator is divided into a number of different elements. These elements can consist of one or more fundamental movements. The movements can be either done by the worker or the machinery.

There are a number of advantages in dividing the different processes into smaller elements. The study results will be more accurate. The non-productive actions can more easily be identified and eliminated. Actions which take place frequently can be standardized and verified against existing data. The correct sequence of the method can be documented and this makes future evaluation more efficient.

8.4.2 Identifying the elements

To ensure that the difficulty level of the study is not unnecessarily increased the beginning, body and ending point of the elements should be clearly defined. There are a number of rules to follow to help with the identification of the element:

- Beginning and end point should be easily recognised, a specific sound of movement
- Do not make the element to big
- Element should follow a certain sequence which is preformed exactly the same on all the object
- A distinction should be made between machine and manual elements
- Repetitive elements should be separated from the irregular movements

Each of the departments present in the facility has a number of processes which are preformed during the manufacturing procedure. Each of these activities can be sub-divided into smaller elements. The different elements which comprise the processes needed to completely produce the vessel are recorded in the table in Appendix G.

8.5 Conducting the study

When conducting the study a decision has to be made about which method will be used. There are two possible techniques to follow to complete the time study namely the continuous timing method and the snapback technique.

The continuous method is rather self explanatory. The stop watch is allowed to run throughout the entire study. The analyst only record the duration of the task at each breakpoint and doesn't reset the stop watch. When the stop watch is reset at a breakpoint the analyst is making use of the snapback technique. The continuous method is better suited for the short-cycle studies where as the snapback technique is predominantly used for long elements. For this project the snapback method was used.

The question also arises about how many cycles should be done to arrive at an equitable standard. The factors that are taken into account include the type of element that is observed and its cycle time. As stated in (Niebel, 2004) the General Electric Company has compiled a list that can be used as an approximated guide to the number of cycles to be observed. The table with the recommended number of observation cycles is illustrated below:

Cycle time in minutes	Recommended number of cycles
0.1	200
0.25	100
0.5	60
0.75	40
1	30
2	20
2-5	15
5-10	10
10-20	8
20-40	5
40-above	3

Table 4: Recommended number of observation cycles

Because most, if not all, of the processes that will be performed at the facility falls within the 40 and above category, no more than 5 observation cycles will be done.

8.6 Discussing the time study form

8.6.1 Rating the operator's performance

The skill of the operator is a determining factor in calculating the actual time needed to complete each element in the process. Rating the performance of the operator assists the analyst in determining a more realistic completion time for the different elements. When the operator is more skilled, the watch time is adjusted upwards and for a poor operator the time is adjusted downwards towards a standard level.

The performance rating is based on how effectively a qualified operator will be able to complete the element. Niebel et al (2003) defines the rating value as a decimal or percentage that is assigned to the observed element. This value is recorded in the R column on the time study form. There are guidelines to determine the correct rating for a specific element.

- For the short-cycle or repetitive work a single or average rating is applied to the whole study
- When the element cycles are longer and entail more diverse manual movements each element is rated separately
- Machinery is rated as normal (100%) because the speed with which the elements are completed do not deviate.

The performance rating is used to adjust the mean observed time of the elements to the time it would take a qualified operator to complete the element. This time is also known as the normal time. The normal time of an element is calculated as follows:

$$NT = OT \times R/100$$

In the equation above OT is the observed time or watch time and R is the performance rating. The performance rating is divided by the standard performance of a qualified operator.

8.6.2 Standard time and allowances

There are a number of interruptions that could occur during a time study. The first is personal interruptions. Trips to the bathroom, kitchen or tee room falls under this description. Extra time must be added to the observed time to compensate for these interruptions. Fatigue is classified as an interruption. The last category of interruptions is the machine and tool failure. This can happen at any time and it requires some degree of variation on the watch time.

Allowance should be added to the normal time to set a reasonable time standard for the operator to complete the element. The reasonable time standard is defined as standard time (ST). The allowance can be calculated in two ways.

- A fraction of the normal time (NT)
- A fraction of the total workday

The following table (Niebel, 2003) can be used as a guide to determine the percentage of allowance for the manufacturing process at Clyde Bergemann

Allowance	**%**
Personal	5
Fatigue	4
Posture: Standing Awkward bending or crouching	2 10
Force: Lifting, pulling or pushing up to 32 kg	0 – 22
Noise levels: Continuous Intermittent – loud High-pitched	0 2 5
Tediousness: Rather tedious Tedious Very tedious	0 2 5

Table 5: Recommended allowances as a percentage

The calculations for the standard time use the following formulas respectively

- $ST = NT \times (1 + \text{allowance})$
- $ST = NT/(1 - \text{allowance})$

The choice of which method to use remains that of the analyst.

8.6.3 Reasonable element time expectations

As stated earlier, there are a number of processes which have not been implemented and thus could not be studied. For this reason reasonable expectations will be used for the following departments:

- Rolling and forming
- Pre-manufacturing
- Welding
- Sandblasting
- Paint

The expected time standard table was compiled with the help of Mr. Roets. He has more than 40 years experience in the manufacturing industry. These times remain estimations and will only be verified and adjusted where needed once the systems are in place.

Department	Element	Expected duration
Rolling and forming	Offloading and nibbler	20
	Inspection	15
	Data package	15
	Guillotine	36
	Flame cutting	70
	Rolling or conical rolling	between 84 - 94 min
	Align and tack	60
Pre-manufacturing	Rolled weld prep	120
	Conical rolled weld prep	120
	Long weld prep	40
	Set up and tag - rolled section	35
	Set up and tag - conical section	45
	FIT UP	20
Welding	Weld rolled section	120
	Weld coniccal section	120
	Weld sections toghether	480
	Steel structure welding	60
	Manhole preparations	60
	Top and bottome flange welding	105
	Prep for x-ray	24
Sandblasting	Sandblasting	105
Paint	1st coat	30
	Drying time	20
	2nd coat	30
	Drying time	20
	3rd coat	30
	Drying time	20

Table 6: Expected time standards

Time studies were conducted on the processes that are available at CBZ. A summary of the results are give in the table that follows. The time study observation forms are shown in Appendix H.

Department	Description	Normal time (NT)	Allowance	Standard time (ST)
Pipes and steelwork	Offload, inspect	9.8	9%	10.7
	Data package	10.4		11.4
	Sawing	28.2		30.8
	Cropping	34.5		37.6
Pre-manufacturing	Steelwork prep	36.9	12%	41.4
Testing	Visual inspection	14.7	5%	15.5
	X-ray	100		105
	Hydro pressure test	116.2		122
Assembly	Complete assembly	348.8	17%	408
	Pipe work assembly	363	17%	424.7
	Steelwork assembly	104.2	17%	121.9
	Remove pipe work	21.4	9%	23.3
Packing	Packing of vessels	9.9	5%	10.4
	Loading and dispatch	8.6		9

Table 7: Summary of the time study results

8.7 Cycle time of the facility

8.7.1 Cycle time defined

The cycle time of a process is the time it takes to complete a specific task within a certain process or rather how long it takes for a part to leave a workstation and move onto the next. The task that is studied can be a certain machine or the time it takes for a product to make it to the market place. Cycle time studies are not only used to calculate the operating time per day of each machine or person present in a facility, it may also be used to determine the following:

- Production rate per unit produced
- Average production output
- The number of resources needed for production to flow fluently
- Benchmark for productivity

8.7.2 Parallel processes

Before the calculations of the process cycle times can be done, the elements that will be performed parallel to each other must first be determined.

This is done to determine the element with the longest completion time which will be converted into the process cycle time. As illustrated in the operation process chart there are

three main process lines that will be running parallel to each other; the pipe and steelwork, vessel body and dome valves. Within each of these process lines are a number of processes that will also be performed in parallel. The discussion of each follows:

In department 1, rolling and forming, there are two processes that will be functioning simultaneously. The body section and the conical sections are rolled on separate machines and thus can be done at the same time.

The pipe and steelwork department also has two processes which will run in parallel with each other. The pipe work can be completed while the steel structures are being formed with the help of the cropper machine. Thus, the cycle time is allocated to the process with the longest completion time.

All the welding preparations can be done independently of each other. By doing this it ensures that the welding station will receive all the components that must be welded together at the same time. If this was not the case there would have been an enormous delay while department 4 must wait for all the components to be tagged together before they are transported for the final welding.

In the welding department there is only one welding manipulator that will complete the work. The cycle time is however not calculated by adding all the element times. The manipulator can weld a number of steams simultaneously and thus the total time before the welded vessel will leave the department is calculated by determining the longest process.

The test and inspection of the welded vessel can only be performed in sequence. This does not however mean that the cycle time will be determined by adding all the relevant times together. Each task within department 5 is performed by a separate person.

The preparation of the pipe and steelwork continuous while the plates are rolled and welded. Once the preparation of these parts is completed they are transported to the department where they will be needed. This process can thus be seen as independent of the primary manufacturing line.

Department 7 is where all the different process lines converge together. The vessel is completely assembled with all the needed parts acquired throughout the facility.

Department 8 and 9 must be completed in sequence and thus there are no parallel processes present.

The loading and dispatch of the dense vessel can only be done after the packing has been completed. Theses however are two elements that can be completed separately. Thus the cycle time will be equivalent to the longest element time.

A summary of all the cycle times of each process in the facility is displayed in table 8. The complete form can be viewed at Appendix I.

9. Simulation

9.1 Departmental simulation

With the knowledge gathered by completing the previous sections the simulation of the facility could commence. These simulations are done to verify the findings and suggestions made throughout this report.

The different departments were simulated to confirm the proposed cycle times. This was done be determining what the bottleneck process are within each department. The process that takes the longest time to complete is the process that will govern the department cycle time. Therefore the waiting time statistic was studied do validate the cycle times.

9.1.1 Description of the simulation process

There are a number of points/factors that must be clarified to understand the results of the Arena model.

Firstly, the expected times for the processes in department 1 is for the complete amount of delivered material. Thus the total time to process one plate is equivalent to the total expected time divided by the amount delivered. The same concept is applicable in department two.

The inspection and data package composition for the delivered material is not done per plate. Instead the whole shipment is inspected together before the separate plates move into the manufacturing line.

Secondly, a triangular distribution was used to model the different processes in the facility. The assumption is made that each activity has an average completion time but this time can deviate between a maximum and minimum completion time.

The inter arrival times are equal to the cycle time of the proceeding process. This will play an important role in the complete facility simulation.

The simulation programmes are shown in Appendix J

9.1.2 Discussing the results

The results of the simulation model are illustrated in Appendix K. These results are discussed below.

Department 2: A study was made of a hypothetical order for 20 units of both pipes and steelwork. The results indicated that the process that will take the longest time to complete is

the cropping process. This validates the suggestion made in Appendix H, the cycle time for department two is governed by the cropper process.

Department 3: In this department there are 3 parallel processes. For the conical preparation line the simulation indicates that the bottleneck process will be the welding preparation. This is what was expected. In the rolled body line of the manufacturing process the simulation again shows that the activity with the longest completion time is the weld preparation. This again verifies the prediction made.

Department 4: As expected the process that takes the longest in this department is welding the sections together. The results shows that there is a considerable waiting time for each section to be welded separately but this is not the times that will influence the cycle time of department 4.

Department 5: In this department the processes needs to be conducted in sequence. The x-ray process can't be completed before the visual inspection. To x-ray the vessels is an expensive process. It would be unwanted to x-ray a vessel to determine defects that could be spotted with the naked eye. The pressure test can also not be completed without the x-rays being done. If there is a defect present and the vessel is placed under pressure serious implications can follow. The cycle time however will still be determined by the longest process because these activities are not performed on the same equipment.

Department 7: The time it takes to completely assemble the dense vessel is the bottleneck element in department 7 and will thus subsequently regulate the total cycle time of the department.

Department 8: In department 8 there is only one element and thus the cycle time for sandblasting will be equal to the time to complete this task.

Department 9: In the paint department the elements present are very repetitive. The three coats applied to the vessels are a requirement from the industry sector where these vessels are implemented. The application of the second and third coats is where this department is hampered.

Department 10: The final department in the manufacturing line is one with a relative short cycle time compared to the rest of the processes. The packing of the vessels were determined to be the longest process, but the simulation illustrated otherwise. According to Arena the loading and dispatching element is the process that will govern department 10's cycle time.

9.2 Complete facility simulation

This project will conclude with the simulation of the complete facility. This is done to verify the findings of the previously completed sections.

Because each of the departments have already been simulated to verify the individual cycle times, the simulation of the complete facility will only feature the cycle time of the different departments. This will result in a far less complicated model. As the manufacturing line becomes more integrated the possibility exists for the facility throughput time to improve.

9.2.1 Discussing the simulation model

Although the processes involved in each department were not included in the simulation of the final facility it was still a rather complex model. To get the right part or material to the right place at the right time was the stumbling block.

The first part of the simulation model illustrates the manufacturing process of the plates and the steel structure for the vessels. The arrival of the plates is simulated as two different events. This is done to ensure that there are an equal number of plates in the system that can be joined together at a later stage. The rolled and conical plate arrivals are moved to department one, where all the processes will be performed as discussed and model in sections 9.1.1. Next the plates are moved to department three where the preparations are done. The times used for these processes as well as all the processes in this simulation model, has already been determined as illustrated in Appendix i.

The next step in the simulation model will be to join one rolled plate and one conical plate into a single unit that will then be moved to the following departments. To achieve this, use was made of the 'signal' and 'wait' block function in *Arena*. The wait block will delay the incoming plate until it receives the signal for its release. The release signal for the rolled plates is connected to the 'number out' of the conical prep process and vice versa. When one of each plate type has been released, they are 'combined' into a single entity.

While the above mentioned process is being performed by *Arena,* the simulation is also engaged with the modulation of the steel work. All the activities of departments 2 and 3 are represented by a single 'process' block respectively. The steel structure is then 'combined' into groups of four. These groups are also sent to a 'wait' block and are only released once the 'number out' for the 'load on trolley' process is equal to one. The plate entity is 'combined' with the steel structure group to form a new single entity, the partly assembled vessel body. This newly formed entity is then sent to the welding department. The above discussed method of simulation is graphically illustrated below.

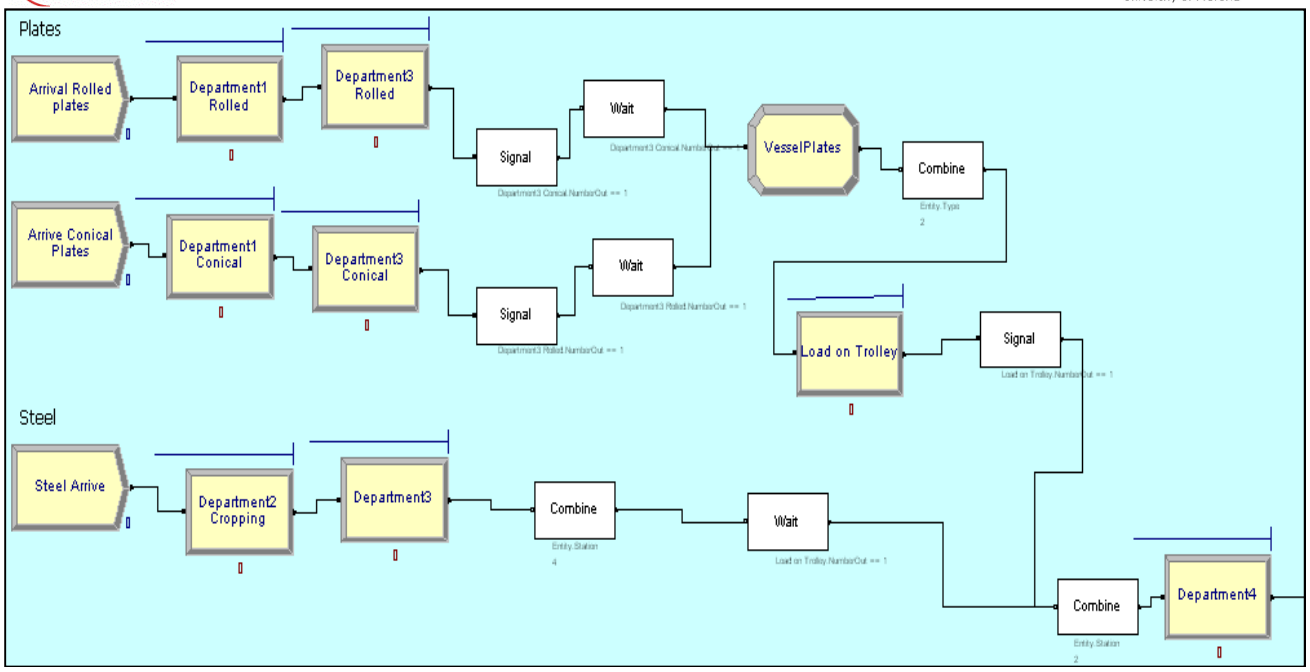

Figure 18: Arena simulation model, part 1

As the simulation program generates rolled and conical plate as well as steel structure arrivals, *Arena* is also creating the arrival of the pipes will be needed for the complete assembly of the vessel. Although the dome valves are an important component of the vessel, they are not represented in the simulation. The fact that the dome valve assembly falls under the operations department of CBZ influenced this decision. The dome valves are delivered to department 7 when they are needed. Thus the dome valves are incorporated into the simulation under the pipe work section.

After the pipes has been processed by department 2 they are 'combined' into groups of the correct size and moves on to a 'wait' block Once the welded vessel is released from the inspection department, the pipe and dome valves are released from the 'wait' block. These entities (the welded plates, the pipes and the dome valves) are 'combined' into yet another new entity. This entity represents the final vessel. This entity moves on to the next department, assembly. The figure below illustrates the process.

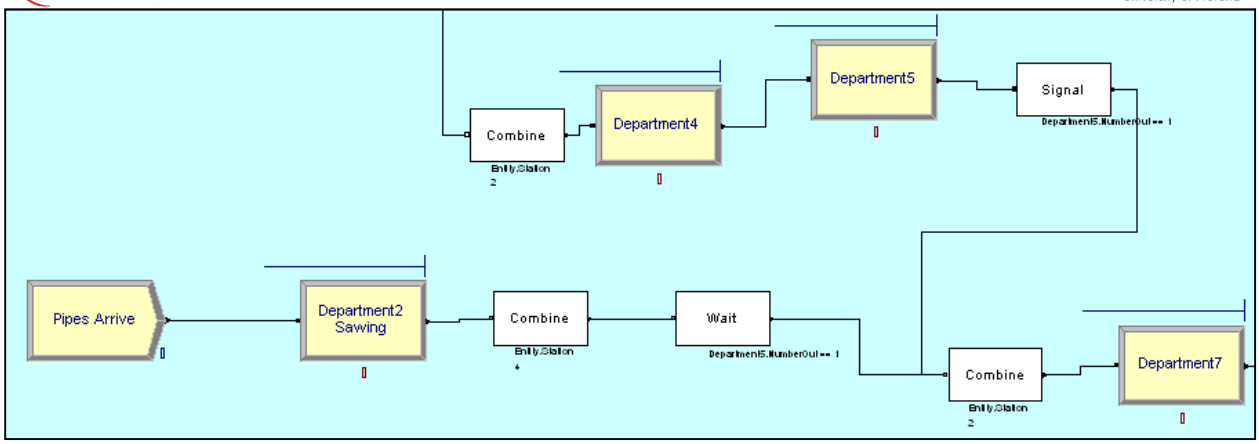

Figure 19 Arena simulation model, part 2

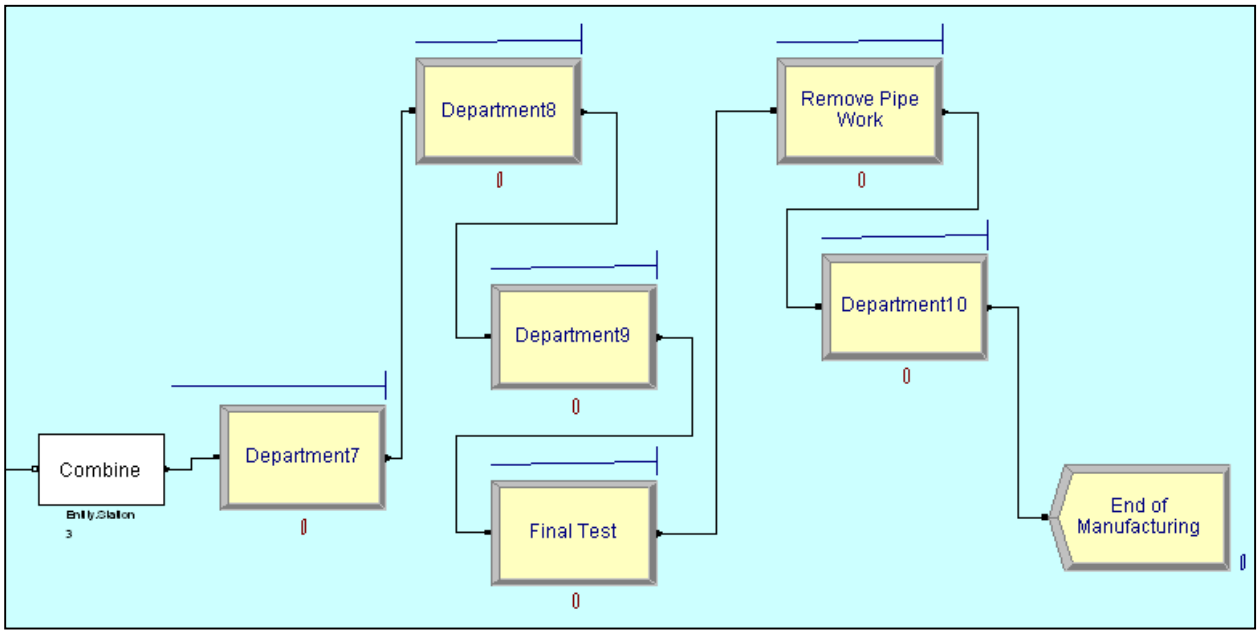

Figure 20: Screenshot of the arena simulation model, part 3

The above figure is an illustration of the final part of the simulation model. The entity created, that represents the final vessel, is moved through the remaining few departments. These departments include sandblasting, painting, final tests, the removal of the pipe work and the packing of the vessels. When these processes are completed the process is terminated.

9.2.2 Result of the final simulation

The final simulation was done to study the manufacturing system as a complete whole. The simulation helped to identify the bottleneck areas and the utilization of the current machinery. These two aspects will assist in focussing future improvement operations at Clyde Beregmann Africa.

With the analysis of the time studies performed, it was established that the welding station will be the bottleneck process of the manufacturing line. This was verified by the simulation. The report sheets can be viewed in Appendix l. The rolling of both types of plates also consumes a large amount of time due to the fact that the rolling process consists of a number of smaller processes and the large number of plates that must be rolled. The same argument is used for the account for the waiting time of the steel work as well as the pipe work.

The machinery with the highest utilization is the welding manipulator and the other equipment of department 4. This is the department were the most work is performed and thus the high utilization rate. The equipment used to assemble the final vessel is also in operation for most of the manufacturing time. For this process all the different production lines converge together to assemble the complete vessel. This in itself is a lengthy process and justifies the utilization rate of the assemble equipment.

9.3 The throughput time for the facility

Calculating the throughput time for the facility the cycle times for the different departments were used. The time estimated here is only the time it will take to manufacture the first vessel. Once the first vessel has been completed the manufacturing line will be able to produce a vessel each day because of the work in progress at the end of the day. The time to complete a vessel is dependent on only the main manufacturing line. The production lines that run in parallel to the main manufacturing line will not affect the calculation of the throughput time. The table below illustrates the total throughput time for the facility at Clyde Bergemann Africa

Department	Cycle time (min)	Cycle time (hour)
Rolling and Forming	94	1.57
Pipe and Steelwork	37	0.62
Pre-manufacture	120	2.00
Welding	480	8.00
Testing	120	2.00
Assembly	425	7.08
Sandblasting	105	1.75
Paint	30	0.50
Removing of pipes	23	0.38
Packing and dispatching	10	0.17
Total throughput time	**1407**	**23.45**

Table 8: Throughput time of the facility

10. Conclusion

Clyde Bergemann Africa is the leader in pneumatic conveying systems. With the proposed workshop in place they will gain a competitive edge over the competition. By manufacturing the vessels themselves a higher quality product can be sent out to the customers creating higher satisfaction rate. The implementation of the proposed facility layout will help to improve the flow of the material and parts through the facility which will result in an increase in the productivity.

Once CBZ has standardized the new workshop, new projects can be accepted. The manufacturing of the soot blowers and ash conditioner is different fields that the company can expand to. Although the capital input into the new workshop is extensive now, the long term goal must be kept in mind. Once the system is in place and operation at optimal levels, the capital expense will be made back with the number of order the workshop receives and with the speed they will be able to produce the orders.

The proposed facility layout and the standardization of the manufacturing process were presented to the relevant people at Clyde Bergemann Africa. A few alterations were discussed and finally made to the presented project. A great improvement was seen with the implementation of the solution to CBZ's stated problem. The possibility was created for the company to venture into a number of different production lines.

As the solutions are continuously implemented accurate information can be gathered to improve the system further.

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12. Appendices

a) Flow process chart

Company:	CBZ	Summary		
Activity:	Pipe work	Event	Present	Proposed
Date:	21/07/2010	Operation	11	
Analyst:	M. Kriel	Transport	7	
Circle appropriate method and type:		Delay	5	
Method:	Present Proposed	Inspection	3	
Type:	Worker Material Machine	Storage	0	

Event Description	Symbol
Offload material	
Inspection	
Assemble data package	
Move to department 2	
Wait to be processed	
Saw to correct size	
Transport to department 7	
Wait to be assembled	
Assemble process	
Test	
Inspection	
Move to sandblasting department	
Await sandblasting	
Sandblasting process	
Move to department 9	
Wait to be painted	
Paint vessel	
Transport to department 5	
Final test	
Final inspection	
Transport to department 7	
Disassemble pipe work	
Move to department 10	
Wait to be packed	
Packing process and dispatch	

		Summary		
Company:	CBZ	Event	Present	Proposed
Activity:	Steelwork	Operation	11	
Date:	21/07/2010	Transport	10	
Analyst:	M. Kriel	Delay	5	
Circle appropriate method and type:		Inspection	3	
Method:	Present Proposed	Storage	0	
Type:	Worker Material Machine			

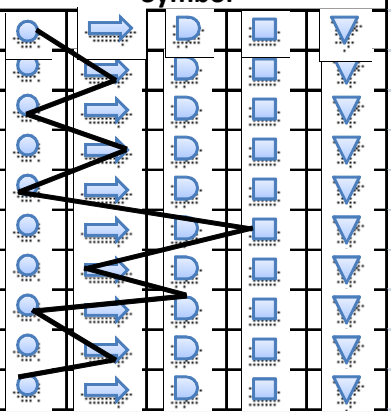
Event Description	Symbol
Offload material	
Inspection	
Assemble data package	
Move to department 2	
Await cropping process	
Cropping	
Move to department 3	
Wait for preparation	
Welding preparation	
Move to department 4	
Wait to be welded to vessel	
Transport to department 5	
Test	
Inspection	
Move to department 7	
Wait to be assembled	
Steel structure assembly	
Transport to department 8	
Sandblasting	
Move to painting department	
Painting process	
Move to department 5	
Final test	
Final inspection	
Transport to department 7	
Removal of pipe work	
Move to department 10	
Await to be packed	
Packing process and dispatch	

Company:	CBZ	Summary		
Activity:	Manufacturing Vessels	Event	Present	Proposed
Date:	21/07/2010	Operation	15	
Analyst:	M. Kriel	Transport	8	
Circle appropriate method and type:		Delay	6	
Method:	Present Proposed	Inspection	3	
Type:	Worker Material Machine	Storage	0	

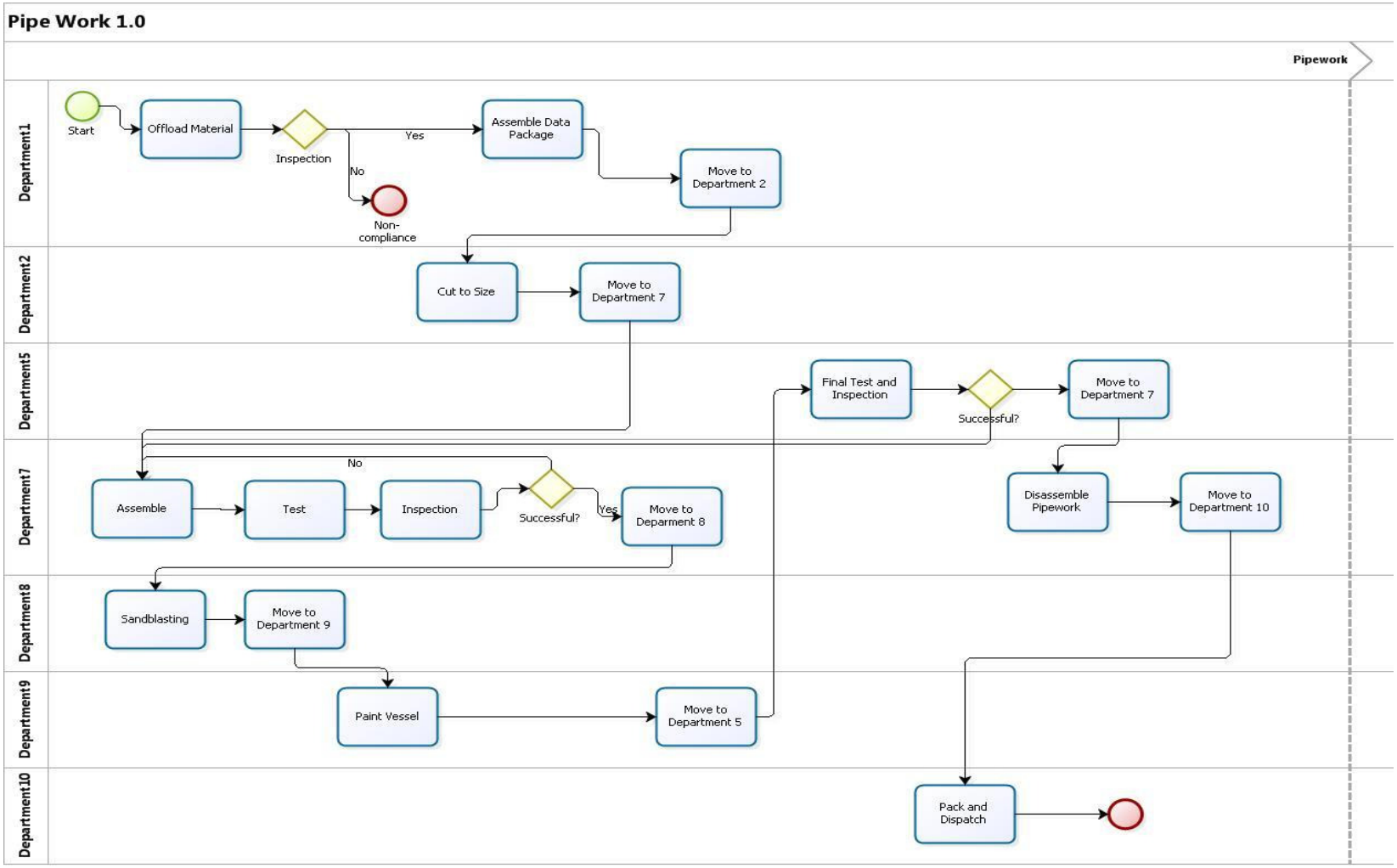
Event Description: Body	Symbol
Offload material	
Inspect	
Assemble data package	
Move to receiving table	
Wait to enter manufacturing process	
Guillotine process	
Move to next process	
Wait for rolling process	
Roll plates	
Move to align and tack queue	
Wait for process	
Align and tack rolled plated	
Transport to department 3	
Await weld preparation	
Rolled weld prep	
Long weld prep	
Setting up and tag the section	
FIT UP	
Transport to department 4	
Wait for welding process	
Weld rolled section	
Weld conical section	
Weld sections together	
Manhole preparations	
Top and bottom flanges	
Prep for department 5	
Move to department 5	
Test	
Inspection	
Move to assembly	
Await assembly	
Assemble dense vessel	
Move to sandblasting department	

Company:	CBZ	Summary		
Activity:	Manufacturing Vessels	Event	Present	Proposed
Date:	21/07/2010	Operation	5	
Analyst:	M. Kriel	Transport	4	
Circle appropriate method and type:		Delay	0	
Method:	Present Proposed	Inspection	1	
Type:	Worker Material Machine	Storage	0	

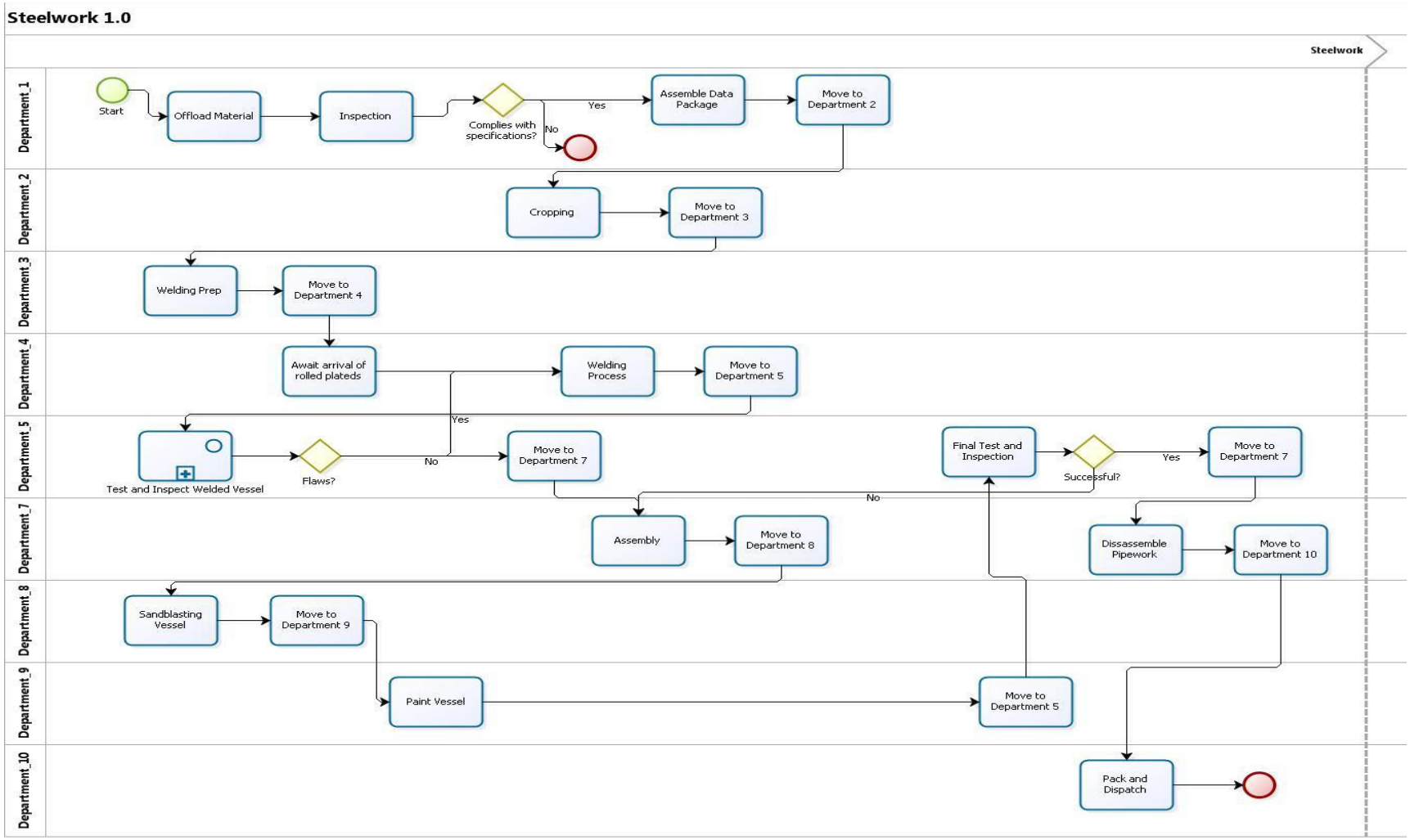
Event Description: Body	Symbol
Sandblasting	
Move to department 9	
Painting	
Move to department 5	
Final test	
Final inspection	
Move to department 7	
Remove pipe work	
Move to department 10	
Packing and dispatch	



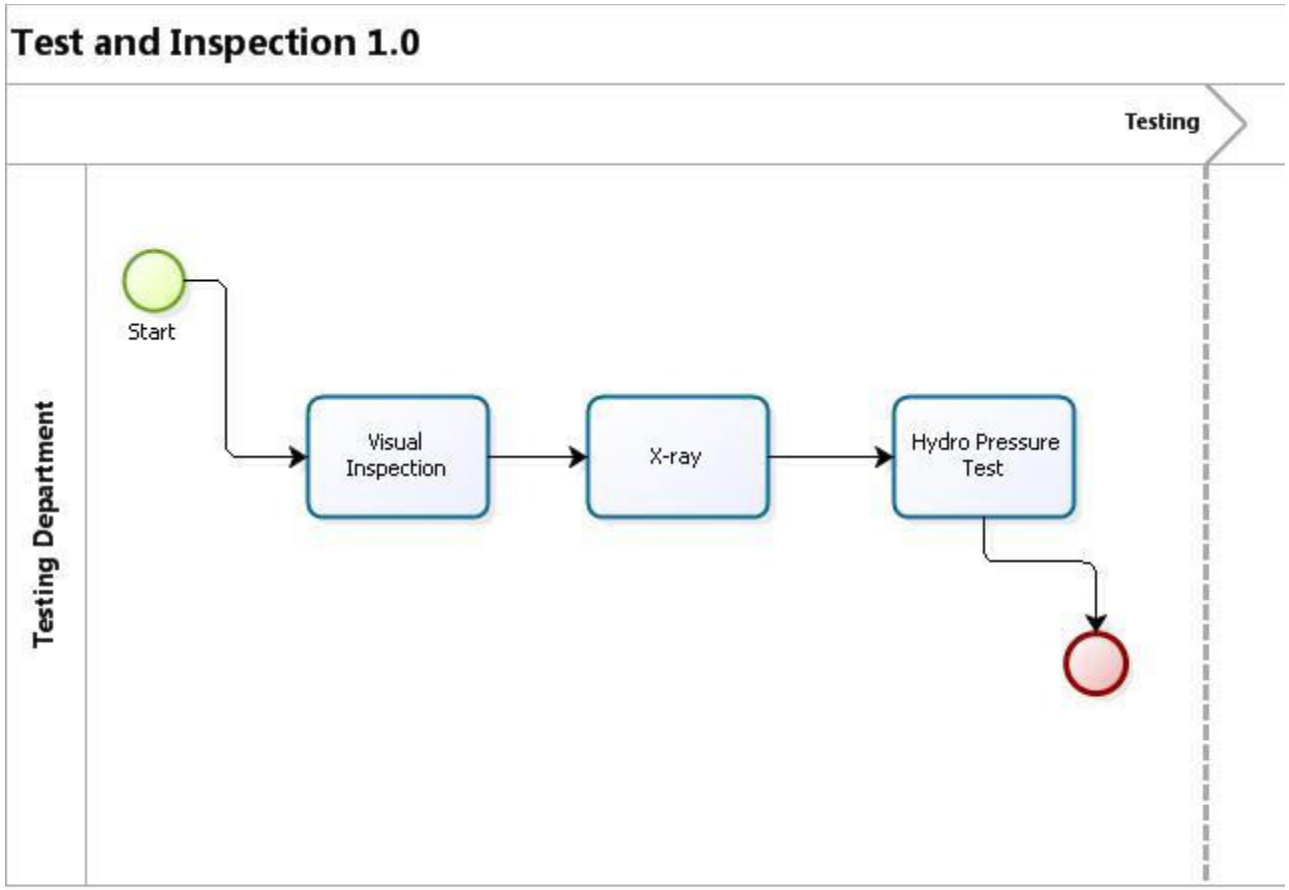
b) Process flow graphically illustrated: Pipe work



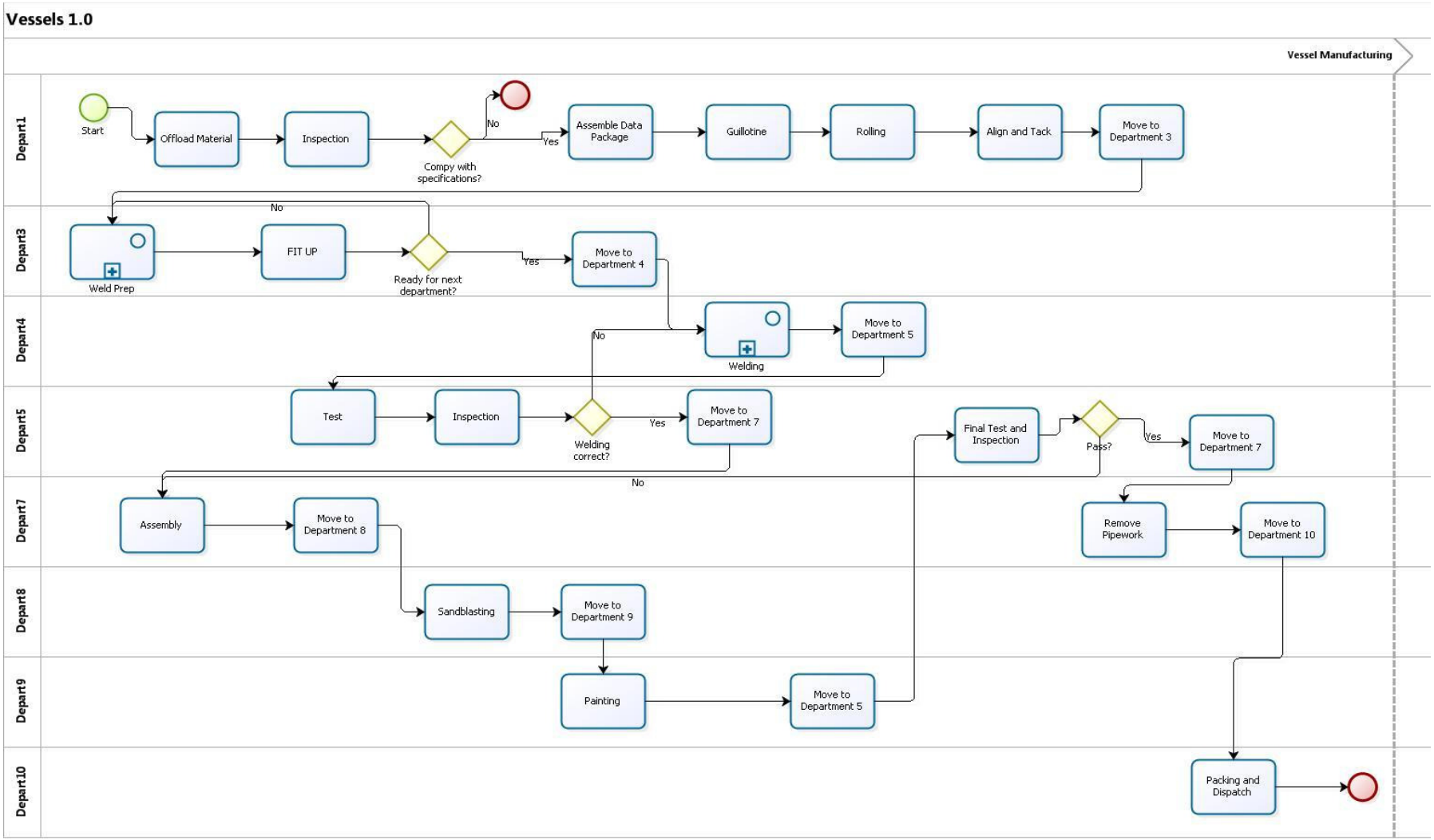
Steel work


Steelwork 1.0
Steelwork
Department_1
Department_2
Department_3
Department_4
Department_5
Department_7
Department_8
Department_9
Department_10
Start
Offload Material
Inspection
Complies with specifications?
Yes
No
Assemble Data Package
Move to Department 2
Cropping
Move to Department 3
Welding Prep
Move to Department 4
Await arrival of rolled plateds
Welding Process
Move to Department 5
Yes
Test and Inspect Welded Vessel
Flaws?
No
Move to Department 7
Final Test and Inspection
Successful?
Yes
Move to Department 7
No
Assembly
Move to Department 8
Dissassemble Pipework
Move to Department 10
Sandblasting Vessel
Move to Department 9
Paint Vessel
Move to Department 5
Pack and Dispatch

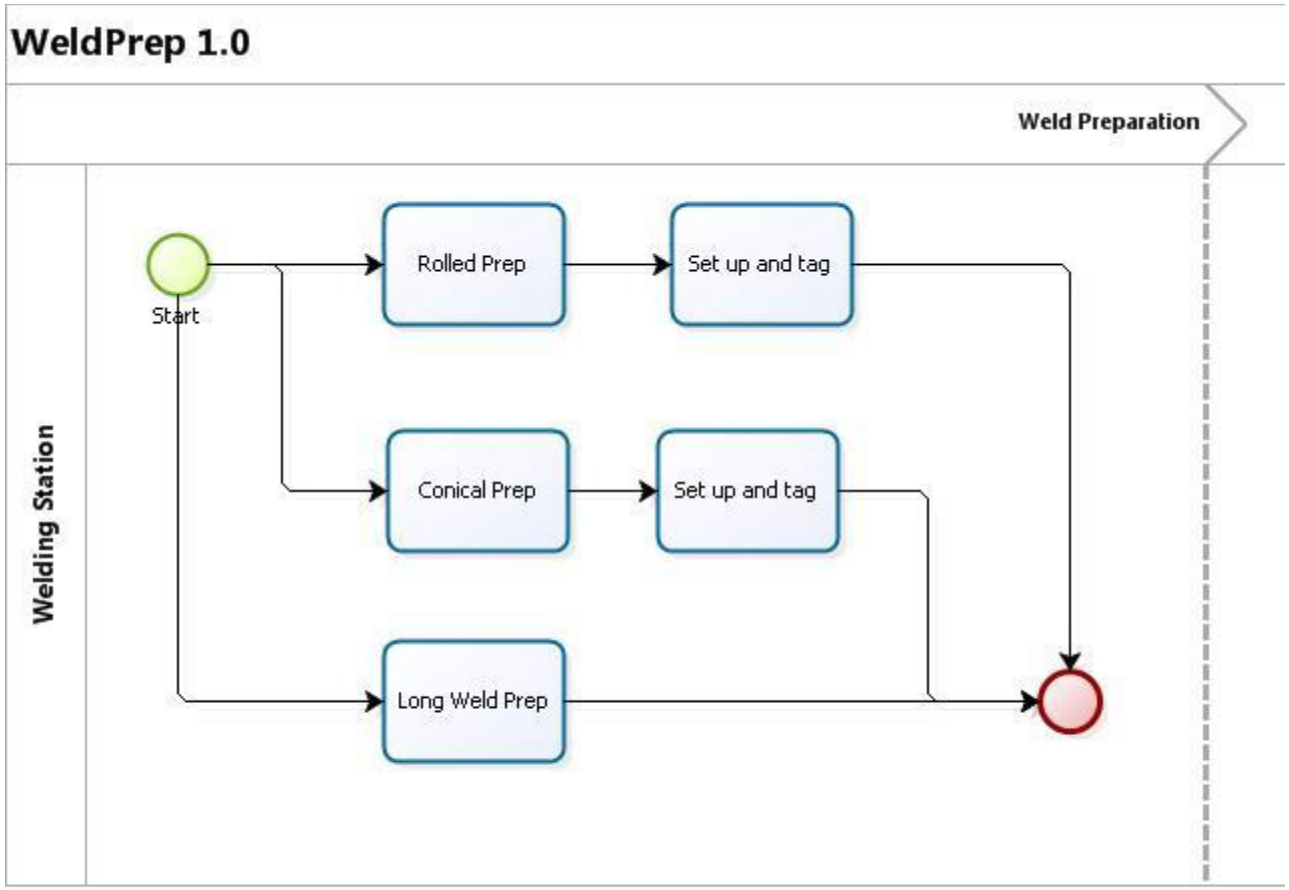
Test and Inspect Welded Vessel Sub-process



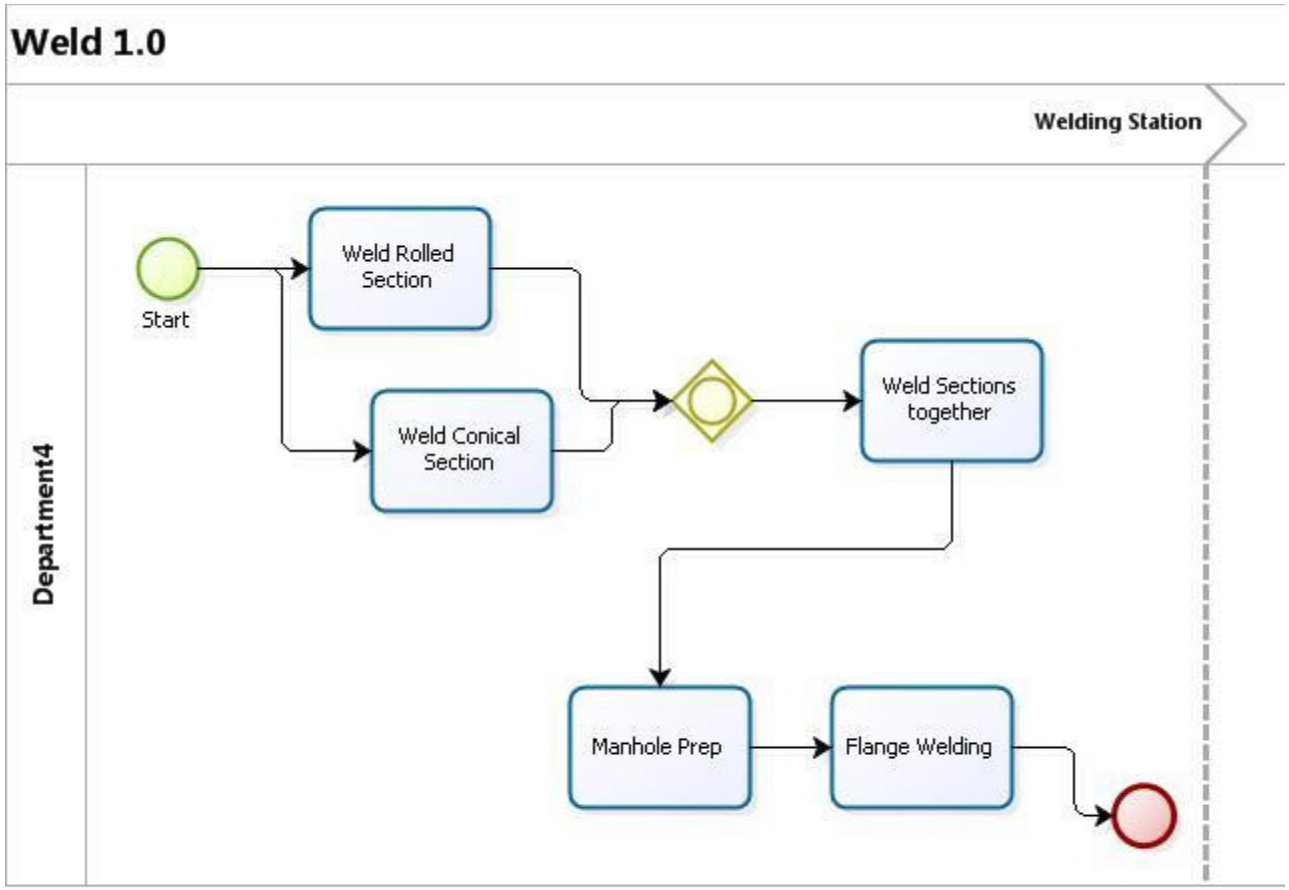
Vessels


Vessels 1.0
Vessel Manufacturing
Depart1
Depart3
Depart4
Depart5
Depart7
Depart8
Depart9
Depart10
Start
Offload Material
Inspection
Compy with specifications?
No
Yes
Assemble Data Package
Guillotine
Rolling
Align and Tack
Move to Department 3
No
Weld Prep
FIT UP
Ready for next department?
Yes
Move to Department 4
No
Welding
Move to Department 5
Test
Inspection
Welding correct?
Yes
Move to Department 7
No
Assembly
Move to Department 8
Sandblasting
Move to Department 9
Painting
Move to Department 5
Final Test and Inspection
Pass?
Yes
Move to Department 7
Remove Pipework
Move to Department 10
Packing and Dispatch

Weld Preparation Sub-process



Welding Sub-process



c) Operation process chart

Company:	Clyde Bergemann Africa (Pty) Ltd				
Prepared by:	M. Kriel				
Product:	Dense vessel				
Date:	2010/06/24				
	Pipe and steelwork		**Vessel body**		**Dome valves**
Department 1	Receive	Department 1	Receive	Department 1	Receive
Department 2	Sizing	Department 1	Cutting	Department 7	Assem
Department 6	Machining	Department 1	Rolling	Department 5	Test
Department 3	Prep	Department 1	Tack		
			Prep		
Department 4			Weld		
Department 5			Test		
Department 7			Assemble		
Departments 8 and 9			Paint		
Department 10			Pack		

d) Departmental service and area requirements sheet

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company:	CBZ	Prepared by:	M. Kriel
Department:	Rolling and forming	Date:	15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Roller	1	1.6	4	7.5	7.5	7.5	7.5	6.4	6	5	17.4
Conical Roller	1	1.6	4	15	15	15	15	6.4	6	5	17.4
Press Brake	1	4.2	1.8	18.5	18.5	18.5	18.5	7.56	6	5	18.56
Guillotine	1	1.8	3.8	18.5	18.5	18.5	18.5	6.84	6	5	17.84
Receiving Table	1	1.2	4.5	0	0	0	0	5.4	6	5	16.4

Net area required	87.6
13% aisle allowance	11.388
Total area required	**98.988**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company:	CBZ	Prepared by:	M. Kriel
Department:	Pipe and steelwork	Date:	15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Saw	1	2	4.5	5.2	5.2	5.2	5.2	9	8	2	19
Hydro Cropper	1	0.6	1.5	5	9	5	9	0.9	8	2	10.9

Net area required	29.9
13% aisle allowance	3.887
Total area required	**33.787**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Pre-manufacture
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Drill	1	1	1	3.9	3.9	3.9	3.9	1	8	10	19
Welding	3	0.26	0.6	45	60	135	180	0.468	20	5	25.468
Workbench	4	1.2	3	0	0	0	0	14.4	8	20	42.4

Net area required	86.868
13% aisle allowance	11.2928
Total area required	**98.1608**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Welding
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
TIG welding	2	0.2	0.5	23	23	46	46	0.2	8	3	11.2
MIG welding	2	0.3	0.5	29	60	58	120	0.3	8	2	10.3
Arc welding	1	0.2	0.6	45	60	45	60	0.12	8	3	11.12
Manipulator	1	3	6	120	120	120	120	18	12	3	33
Holding ovens	3	0.4	0.4	22	22	66	66	0.48	2	2	4.48
Heat treatment	1	0.8	1.2	75	75	75	75	0.96	12	3	15.96
Workbench	2	1.2	3	0	0	0	0	7.2	0	2	9.2

Net are required	95.26
13% aisle allowance	12.3838
Total are required	**107.644**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Testing
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
9bar Compressor	1	1.2	0.7	60	60	60	60	0.84	2	1	3.84
Soot blower test panel	1	1.3	1	2	2	2	2	1.3	2	1	4.3
Valve hydraulic testing	1	1.2	0.8	5	5	5	5	0.96	2	1	3.96
Pressure testing	1	1.2	1.2	2.5	2.5	2.5	2.5	1.44	2	1	4.44
Workbench	1	1.2	3	0	0	0	0	3.6	2	1	6.6
Pallets	1	1	0.6	0	0	0	0	0.6	2	1	3.6
X-ray process	n/a	5	3	0	0	0	0	15	2	1	18

Net area required	44.74
13% aisle allowance	5.8162
Total area required	**50.5562**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Manufacturing
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Lathe	1	1.5	4	9.25	22	9.25	22	6	5	3	14
Bench grinder	1	1	1	1.7	1.7	1.7	1.7	1	6	3	10
Milling	1	1.5	1.6	2.2	2.2	2.2	2.2	2.4	6	2	10.4
Workbench	2	1.2	3	0	0	0	0	7.2	7	2	16.2

Net area required	50.6
13% aisle allowance	6.578
Total area required	**57.178**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Assembly
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Workbench	3	1.2	3	0	0	0	0	10.8	4	2	16.8
Compressor	1	0.7	1.2	60	65	60	65	0.84	6	3	9.84
Assembly	4	5	5	0	0	0	0	100	6	4	110

Net area required	136.64
13% aisle allowance	17.7632
Total area required	**154.403**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Sandblasting
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Sandblasting	1	5	5	15	15	15	15	25	3	2	30
Washing	1	3	3	15	15	15	15	9	3	2	14

Net area required	44
13% aisle allowance	5.72
Total area required	**49.72**

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Painting
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Painting booth	1	5	5	15	15	15	15	25	3	2	30
Washer	1	3	3	15	15	15	15	9	3	2	14
Drying area	1			0	0	0	0	0	5	5	10

Net area required	54
13% aisle allowance	7.02
Total area required	**61.02**

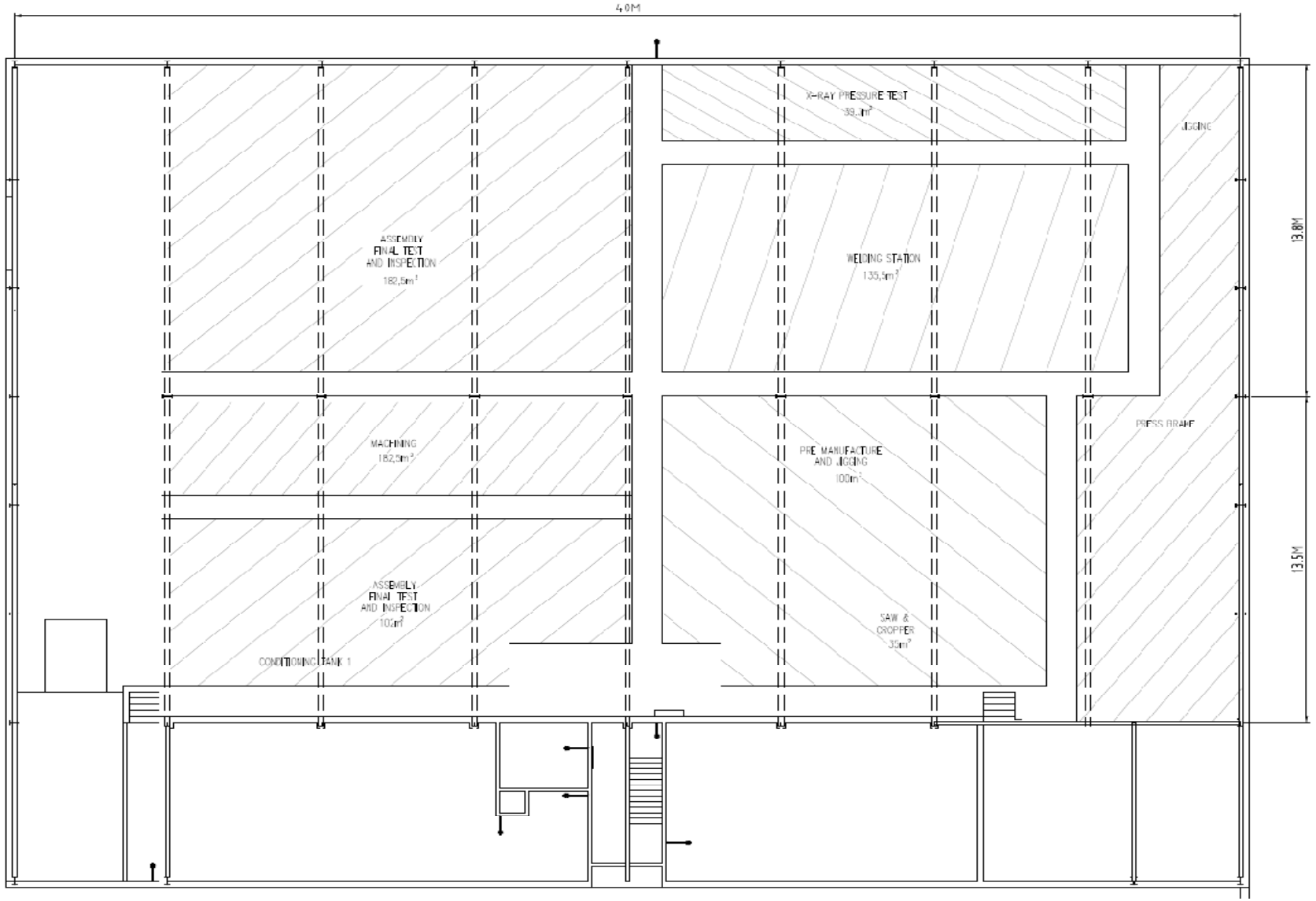
DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company: CBZ
Department: Packing
Prepared by: M. Kriel
Date: 15/06/2010

		Dimensions		Service Requirements				Area (m^2)			
Workstation	**Quantity**	**Width**	**Length**	**Min kW**	**Max kW**	**Total min**	**Total max**	**Equipment**	**Material**	**Personnel**	**Total**
Packing	3	4.78	4.4	65	65	65	65	63.096	0	3	66.096

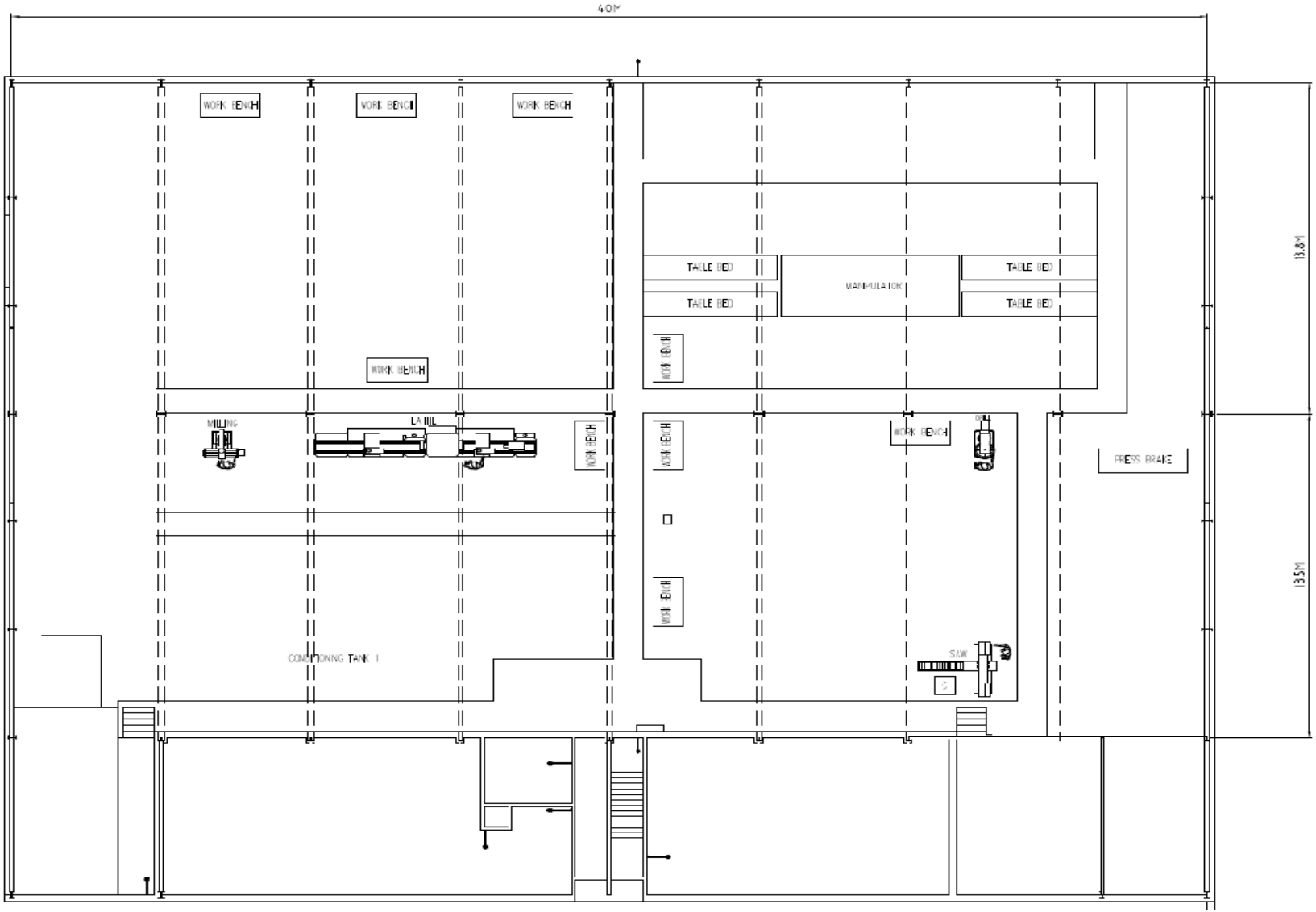
Net area required	66.096
13% aisle allowance	8.59248
Total area required	**74.6885**

e) Detailed layout of the chosen option: Departmental layout



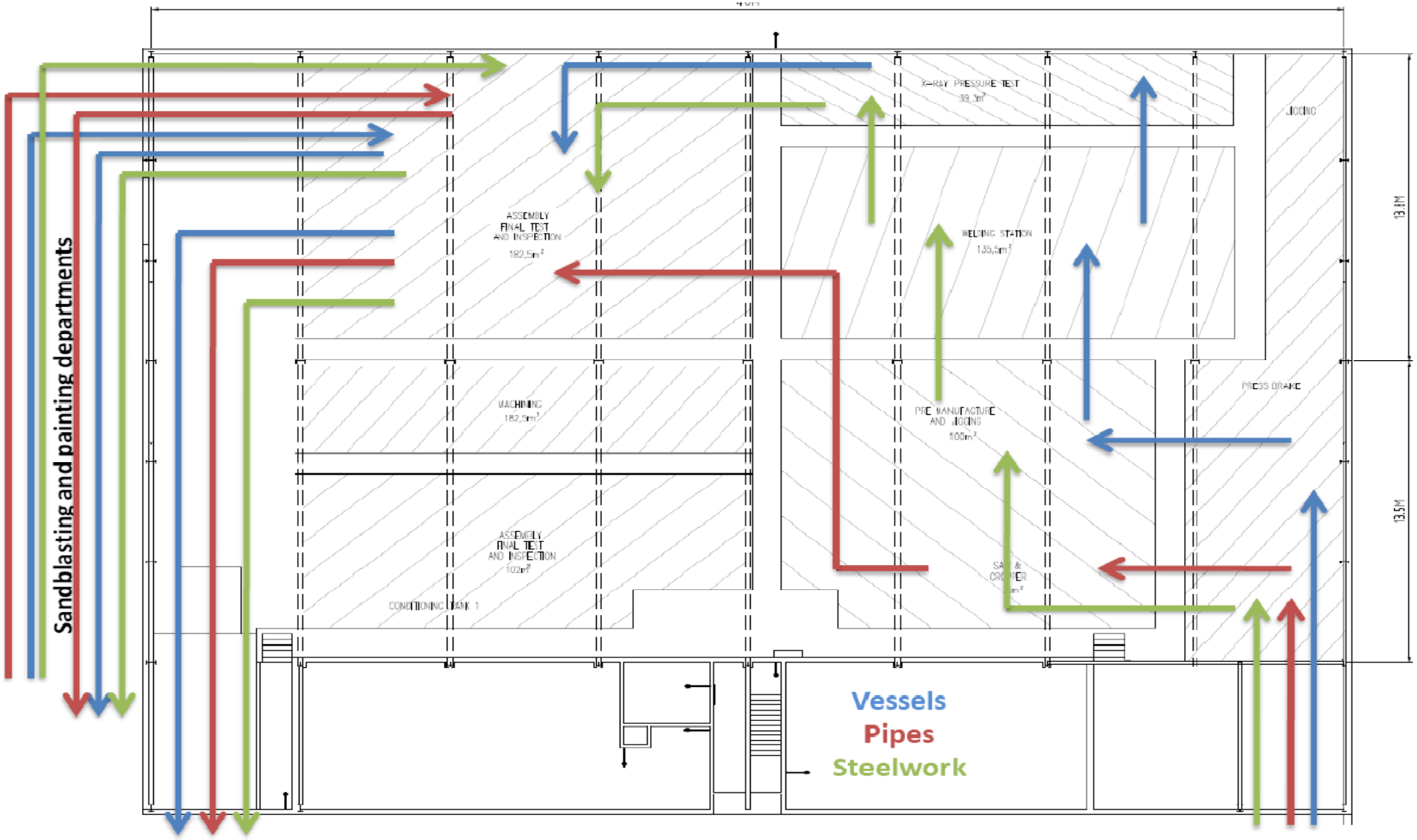
Drawing 1: *Detailed layout of the chosen option: Departmental layout,* CBZ Drawing office, 2009

Machinery layout



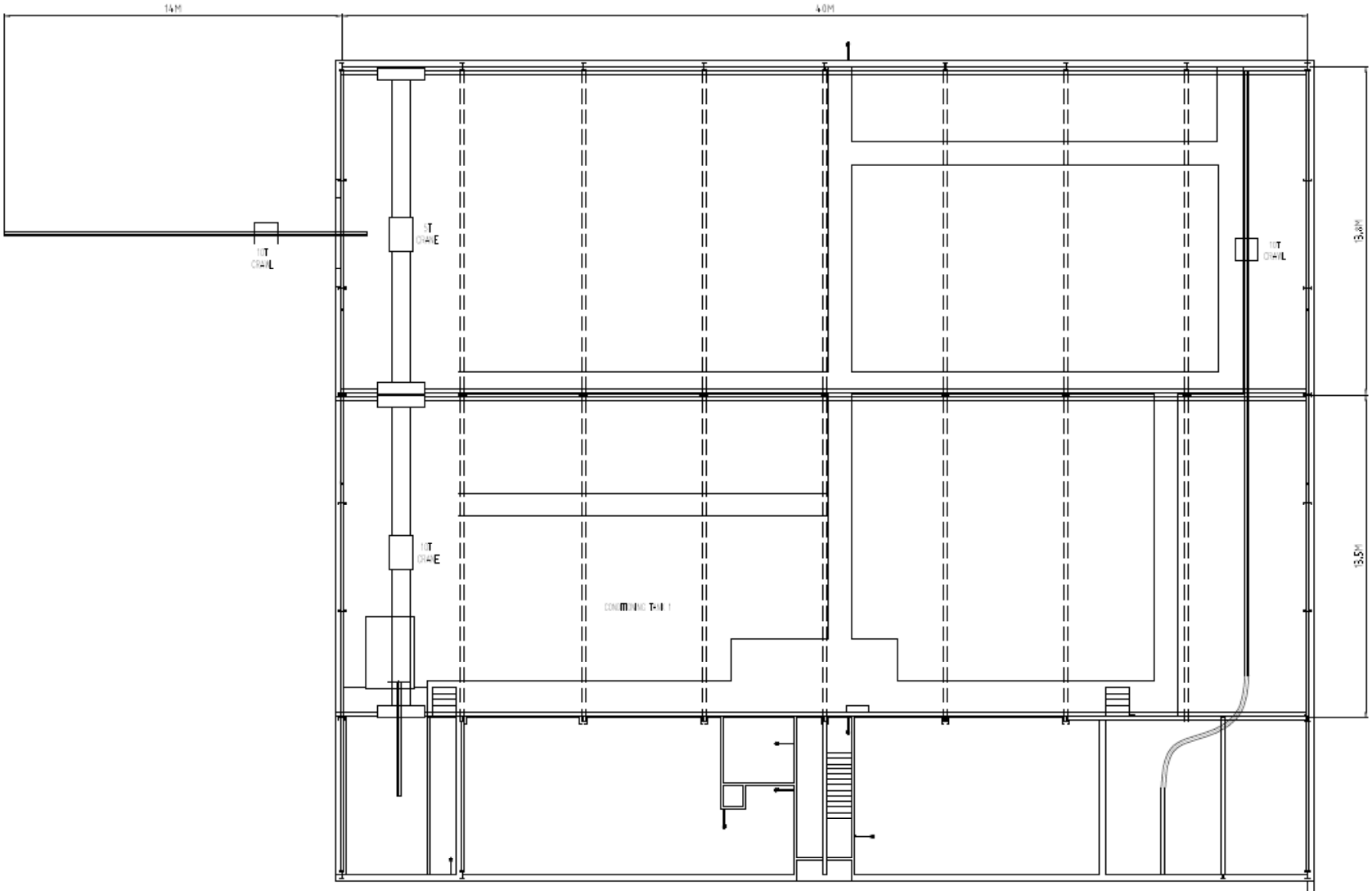
Drawing 2: *Machinery layout,* CBZ Drawing Office, 2009

Flow through the facility



Drawing 3: *Flow through the facility*, CBZ Drawing Office, 2009

f) Material handling system layout



Drawing 4: *Material handling system layout,* CBZ Drawing Office, 2009

g) Elements of the different processes

Department	Process	Elements
Rolling and forming	Offloading and nibbler	Offload material and place on appropriate stack
	Inspection	Inspect received material and sign release form
	Data package	Compile data package and move material to 1st process
	Guillotine	Load material and set up of machinery, cut the plates and place on stack of next process
	Flame cutting	Cut plates for conical section and move to conical roller queue
	Rolling of conical rolling	Place plates into machine and set up, roll plates, remove from machine and move to next process
	Align and Tack	Align edges of rolled plates and tack together and mover to department 3
Pipe and steelwork	Inspection	Inspect received material and sign release form
	Data package	Compile data package and move material next process
	Saw	Load, set up and sawing material into correct lengths and move to department 7
	Cropping	Load material, set up machine, form into right shape and transport to welding station
Pre manufacturing	Rolled weld prep	Welding prep done on rolled section and moved to welding station queue
	Conical rolled weld prep	Welding prep done on conical section and moved to welding station queue
	Long weld prep	Long weld preparation done and moved to welding station
	Set up and tag - rolled section	Align edges of rolled plates and tack together and mover to department 4
	Set up and tag - conical section	Align edges of conical rolled plates and tack together and move to department 4
	FIT UP	Start inspection and sign off if welding complies with standards
Welding	Weld rolled section	Load rolled section onto manipulator, weld section and remove from machine
	Weld conical section	Load conical section onto manipulator, weld section and remove from machine
	Weld sections together	Load rolled and conical sections onto manipulator and weld together and remove

Department	Process	Elements
Welding	Steel structure welding	Weld steel structure to body of vessel and move to prep area
	Manhole preparation	Start and complete manhole preparation
	Top and bottom flange welding	Weld top and bottom flanges to vody of vessel
	Prep for x-ray	Clean vessel for inspection and move to department 5
Testing	Visual inspection	Visually inspect vessel and document
	X-ray	Take x-ray images of welds and study results
	Hydro pressure test	Commence test and drain water from vessel once completed
Assembly	Dome valve	Assemble dome valves and move to assemble table for use in vessel assembly
	Complete assembly of vessel	Commence the assemble process and prepare for the pipe work
	Assemble pipe work	Assemble pipe work onto vessel and prepare for steel structure assembly
	Assemble steel structure	Assemble steel structure onto vessel and move to department 8
	Remove pipe work	Remove pipe work from vessel and move to department 10
Sandblasting	Sandblasting	Sandblast vessel and move to paint booth
Paint	1st coat	Paint 1st coat on vessel and move to drying area
	Drying time	Let paint dry and transport back into paint booth
	2nd coat	Paint 2nd coat on vessel and move to drying area
	Drying time	Let paint dry and transport back into paint booth
	3rd coat	Paint 3rd coat on vessel and move to drying area
	Drying time	Let paint dry and transport back into paint booth
Packing	Packing of vessel	Wrap vessel in needed protection and pack into correct packaging
	Loading	Load packaged vessel onto transportation medium and dispatch

h) Time study observation form

Time study observation form				Study no.: 1-2			Date: 28 June '10			Page: 1 of 1		
				Operation: Pipe and steelwork			Operator:			Observer: Kriel		
Element no. and description	1 Offload and inspection			2 Data package			3 Load, set-up and saw. Move to D7			4 Load, set-up and crop. Move to D3		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT	R	OT	NT
1	70	12	8.4	85	10	8.5	90	25	22.5	100	37	37
2	110	8	8.8	90	13	11.7	100	30	30	90	30	27
3	100	12	12	100	12	12	110	35	38.5	80	28	22.4
4	75	17	12.75	120	8	9.6	100	31	31	110	40	44
5	100	10	10	96	11	10.56	80	25	20	100	37	37
6	80	9	7.2	70	16	11.2	100	30	30	85	30	25.5
7	95	10	9.5	95	10	9.5	95	27	25.65	115	42	48.3
8												
9												
10												
Summary												
Total OT	78			80			203			244		
Rating												
Total NT	68.65			73.06			197.65			241.2		
No. of cycles	7			7			7			7		
Average NT	9.8			10.4			28.2			34.5		
% Allowance	0.09			0.09			0.09			0.09		
Standard time	10.7			11.4			30.8			37.6		
Allowances				**Remarks:**								
Personal	0.05			Total standard time for department 2: 90.5 min								
Fatigue	0.04											
Special	0											
Total	0.09											

Time study observation form				Study no.: 1-3			Date: 28 June '10			Page: 1 of 1		
				Operation: Pre manufacturing			Operator:			Observer: Kriel		
Element no. and description	1 Steelwork prep			2			3			4		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT	R	OT	NT
1	80	45	36									
2	90	68	61.2									
3	100	60	60									
4	95	57	54.15									
5	110	52	57.2									
6			0									
7			0									
8			0									
9			0									
10			0									
Summary												
Total OT	282											
Rating												
Total NT	268.55											
No. of cycles	5											
Average NT	53.7											
% Allowance	0.12											
Standard time	60.2											
Allowances				**Remarks:**								
Personal	0.05			Total standard time for department 3: 60.2 min								
Fatigue	0.04											
Special	0.03											
Total	0.12											

Time study observation form				Study no.: 1-3			Date: 28 June '10			Page: 1 of 1		
				Operation: Pre manufacturing			Operator:			Observer: Kriel		
Element no. and description	1 Steelwork prep			2			3			4		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT	R	OT	NT
1	80	45	36									
2	90	36	32.4									
3	100	40	40									
4	95	42	39.9									
5	110	33	36.3									
6			0									
7			0									
8			0									
9			0									
10			0									
Summary												
Total OT	196											
Rating												
Total NT	184.6											
No. of cycles	5											
Average NT	36.9											
% Allowance	0.12											
Standard time	41.4											
Allowances				**Remarks:**								
Personal	0.05			Total standard time for department 3: 41.4 min								
Fatigue	0.04											
Special	0.03											
Total	0.12											

Time study observation form				Study no.: 1-7			Date: 20 June'10			Page: 1 of 2		
				Operation: Assembly			Operator:			Observer: Kriel		
Element no. and description	2	Complete assembly of vessel		3	Pipe work assembly		4	Assemble steel structure		4		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT			
1	75	390	292.5	100	420	420	85	123	104.6			
2	100	405	405	72	425	306	100	120	120			
3			0			0	105	113	118.7			
4			0			0	80	124	99.2			
5			0			0	75	105	78.75			
6			0			0			0			
7			0			0			0			
8			0			0			0			
9			0			0			0			
10			0			0			0			
Summary												
Total OT	795			845			585					
Rating												
Total NT	697.5			726			521.15					
No. of cycles	2			2			5					
Average NT	348.75			363.0			104.23					
% Allowance	0.17			0.17			0.17					
Standard time	408.0			424.7			121.9					
Allowances				**Remarks:**								
Personal	0.05			Total standard time for department 7: 954.6 min								
Fatigue	0.04											
Special	0.08											
Total	0.17											

Time study observation form				Study no.: 1-7			Date: 20 June'10			Page: 2 of 2		
				Operation: Assembly			Operator:			Observer: Kriel		
Element no. and description	1 Remove pipe work			2			3			4		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT	R	OT	NT
1	85	32	27.2									
2	105	17	17.85									
3	100	22	22									
4	95	28	26.6									
5	100	20	20									
6	120	15	18									
7	60	30	18									
8			0									
9			0									
10			0									
Summary												
Total OT	164											
Rating												
Total NT	149.65											
No. of cycles	7											
Average NT	21.4											
% Allowance	0.09											
Standard time	23.3											
Allowances				**Remarks:**								
Personal	0.05			Total standard time for department 7: 23.3 min								
Fatigue	0.04											
Special	0											
Total	0.09											

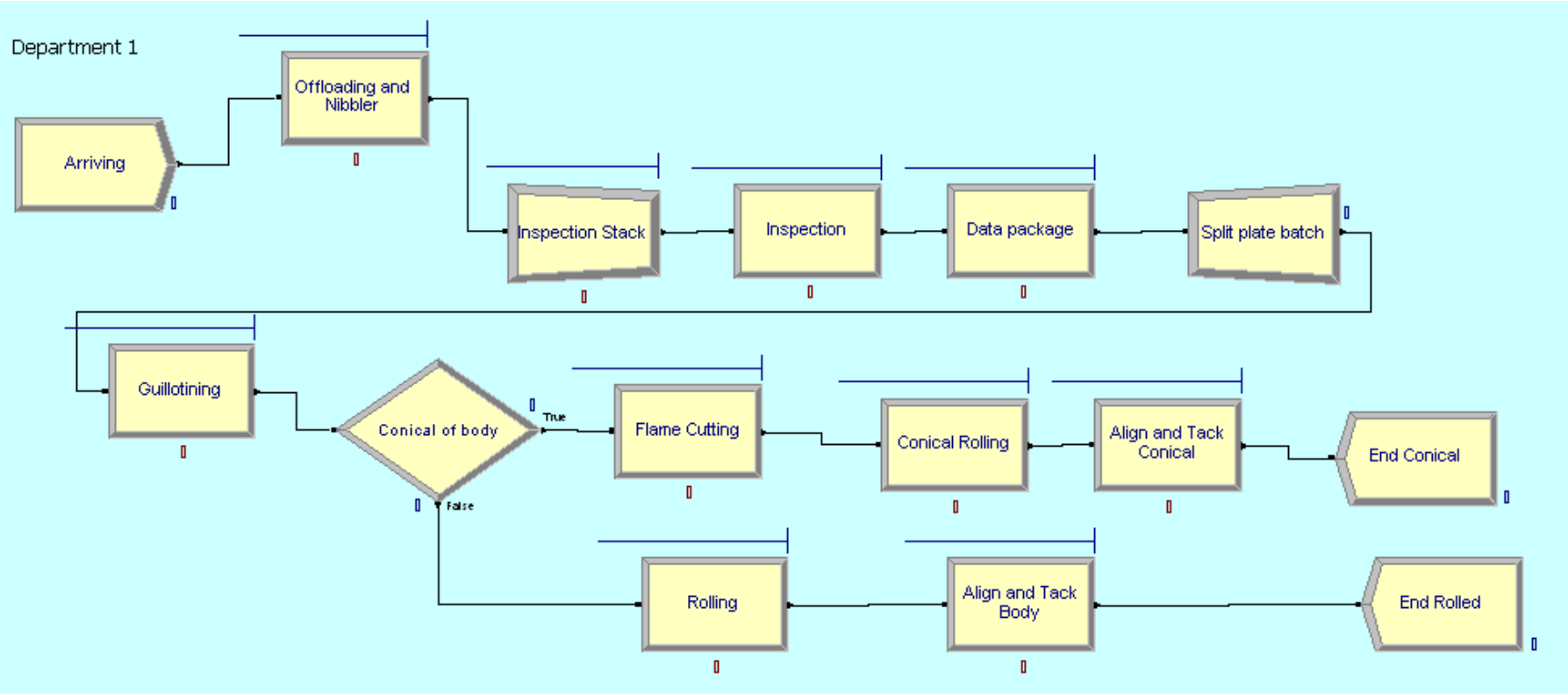
Time study observation form				Study no.: 1-10			Date: 8 july '10			Page: 1 of 1		
				Operation: Packing			Operator:			Observer: Kriel		
Element no. and description	1 Packing of vessel			2 Loading and dispatch			3			4		
Cycle	R	OT	NT	R	OT	NT	R	OT	NT	R	OT	NT
1	90	14	12.6	100	8	8						
2	105	8	8.4	85	12	10.2						
3	100	10	10	110	6	6.6						
4	80	16	12.8	90	14	12.6						
5	110	7	7.7	100	8	8						
6	95	10	9.5	105	7	7.35						
7	105	11	11.55	80	10	8						
8	100	7	7	70	11	7.7						
9			0			0						
10			0			0						
Summary												
Total OT	83			76								
Rating												
Total NT	79.55			68.45								
No. of cycles	8			8								
Average NT	9.9			8.6								
% Allowance	0.05			0.05								
Standard time	10.4			9.0								
Allowances				**Remarks:**								
Personal	0.05			Total std time for department 10: 19.4								
Fatigue	0											
Special	0											
Total	0.05											

i) Parallel processes with cycle times

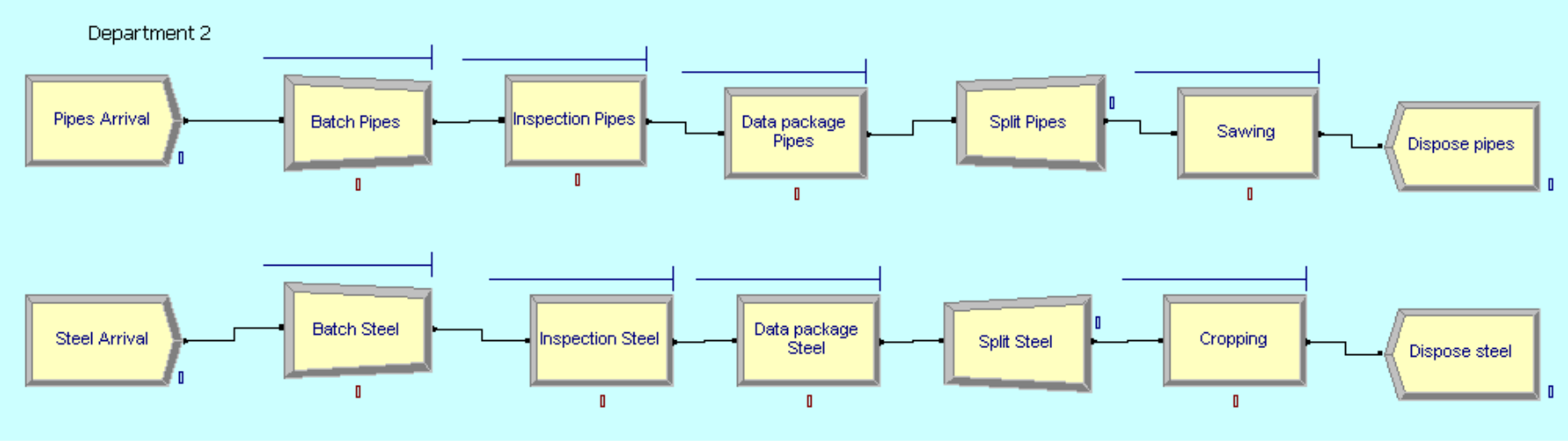
Department	Element	Task	Time	Cycle Time (in min)
1	Rolling (Body)	Offloading and Nibbler	20	
		Inspection	15	
		Data package	15	
		Guillotine	36	
		Rolling	84	
		Align and Tack	60	84
	Rolling (Cone)	Offloading and Nibbler	20	
		Inspection	30	
		Data package	15	
		Guillotine	36	
		Flame Cutting	70	
		Conical Rolling/Press Brake	94	
		Align and Tack	60	94
2	Steel and pipe work	Offload, inpect	10	
		Data package	12	
		Steel Structure preparation	37	
		Pipe Preparation	30	37
3	Rolled	Weld Preparation	120	
		Setting up and tag	35	120
	Conical	Weld Preparation	120	
		Setting up and tag	45	120
	Steel	Steelwork prep	40	60
	Normal	Weld Preparation	120	120
	FIT UP before next department: Welding Station		20	20
4	Vessel	Weld rolled section	120	
		Weld conical section	120	
		Weld section together	480	
		Manhole preparation	60	
		Top and bottom flanges	105	
		Prepare for x-rays	24	480
	Steel	Steel Structure welding	60	60
5	Visual inspection		15	15
	X-rays		105	105
	Pressure	Pressure Test	120	120
7	Final	Assembly of complete MD-pump	408	
		Pipe work	425	
		Steel Structure	122	425

Department	Element	Task	Time	Cycle Time (in min)
8	Sandblasting		105	105
9	1st	Painting	30	30
		Drying	20	
	2nd	Painting	30	30
		Drying	20	
	3rd	Painting	30	30
		Drying	20	
7	Stripping of pipes from vessel		23	23
10	Pack	Packing of vessel	10	10
		Loading and dispatch	9	

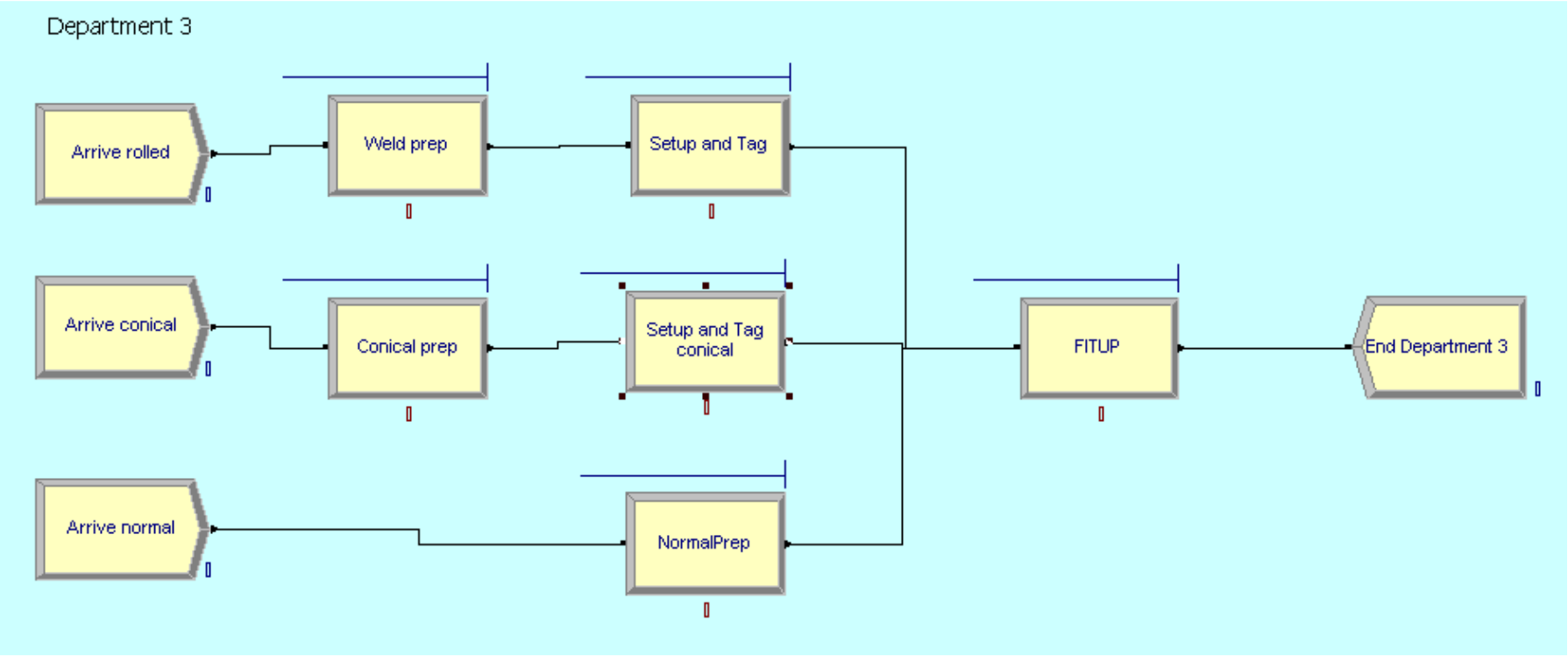
j) Simulation programmes
Department 1



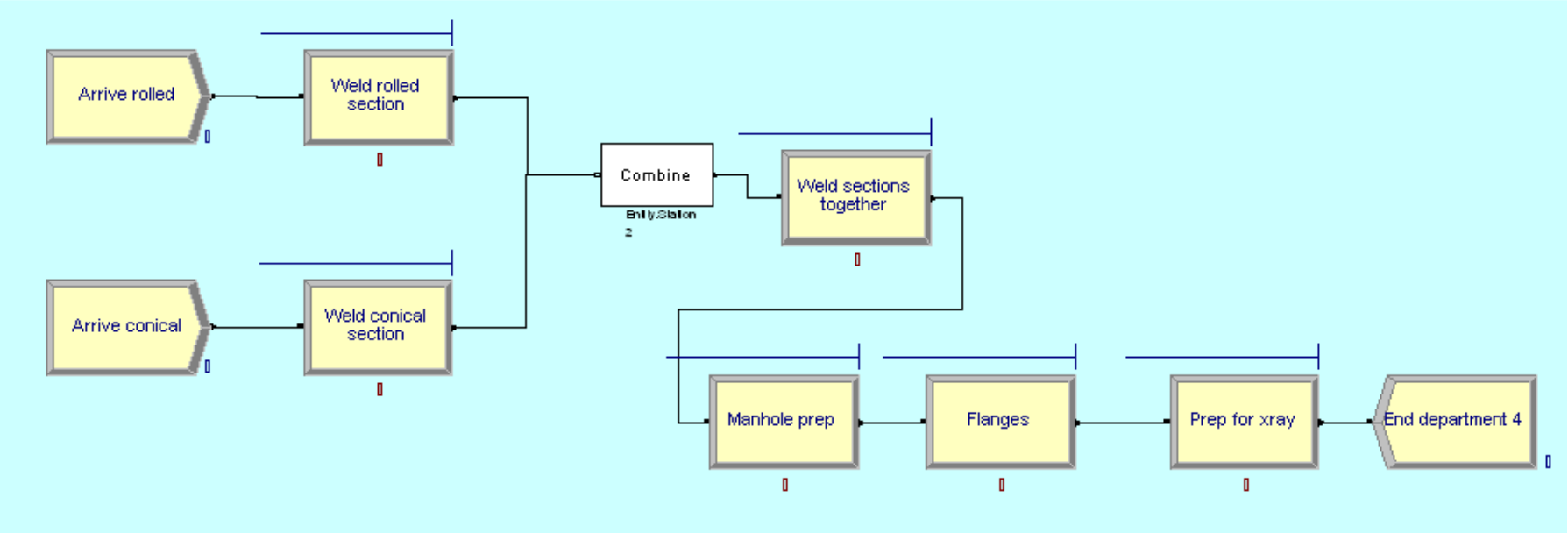
Department 2



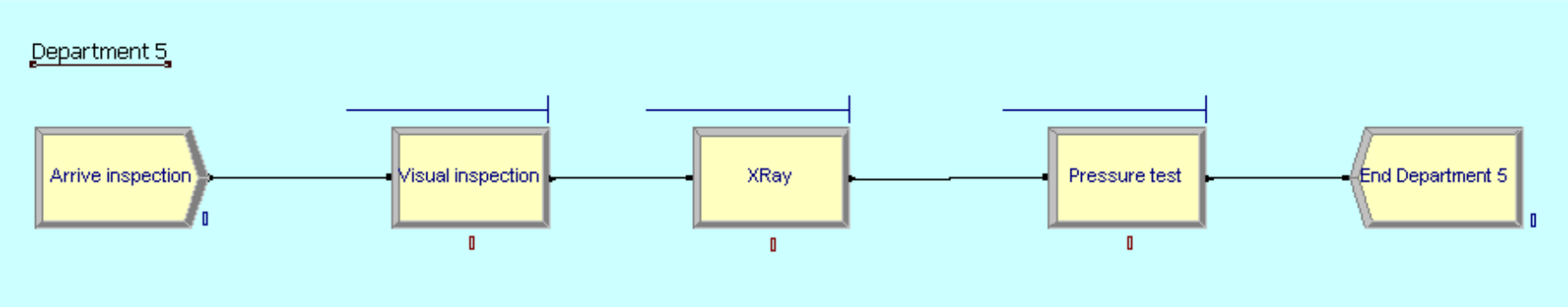
Department 3



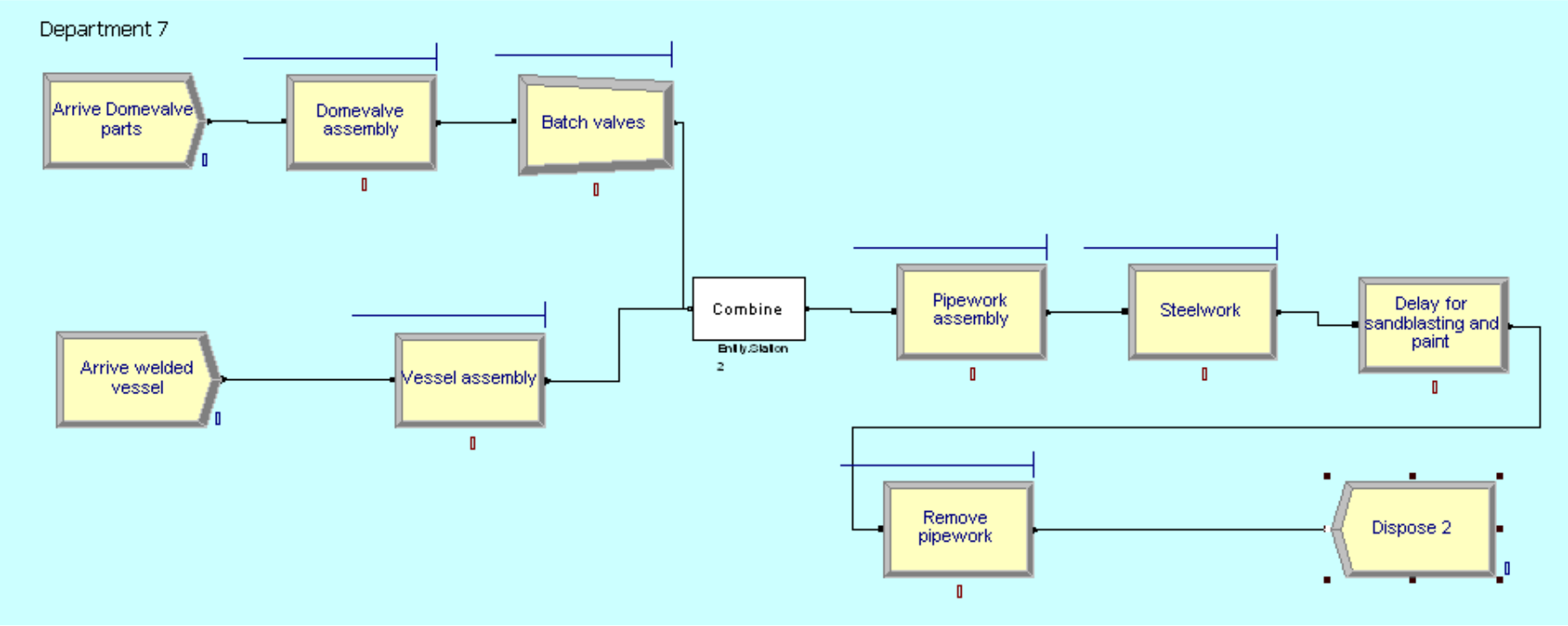
Department 4



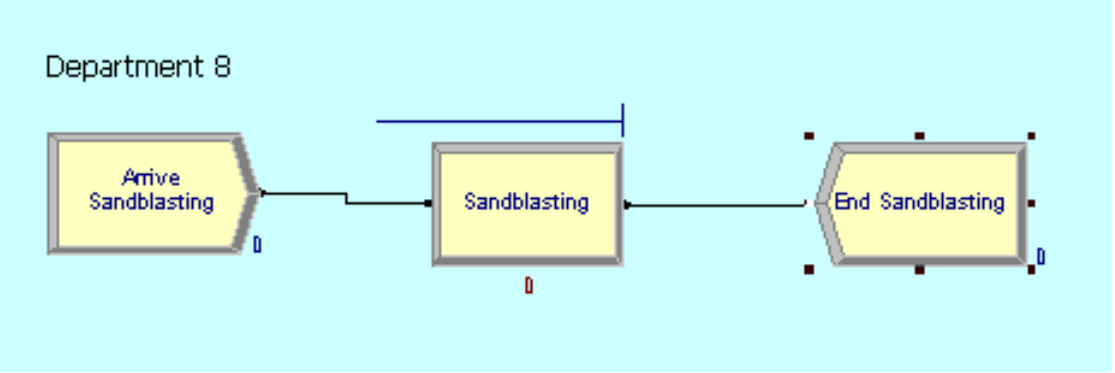
Department 5



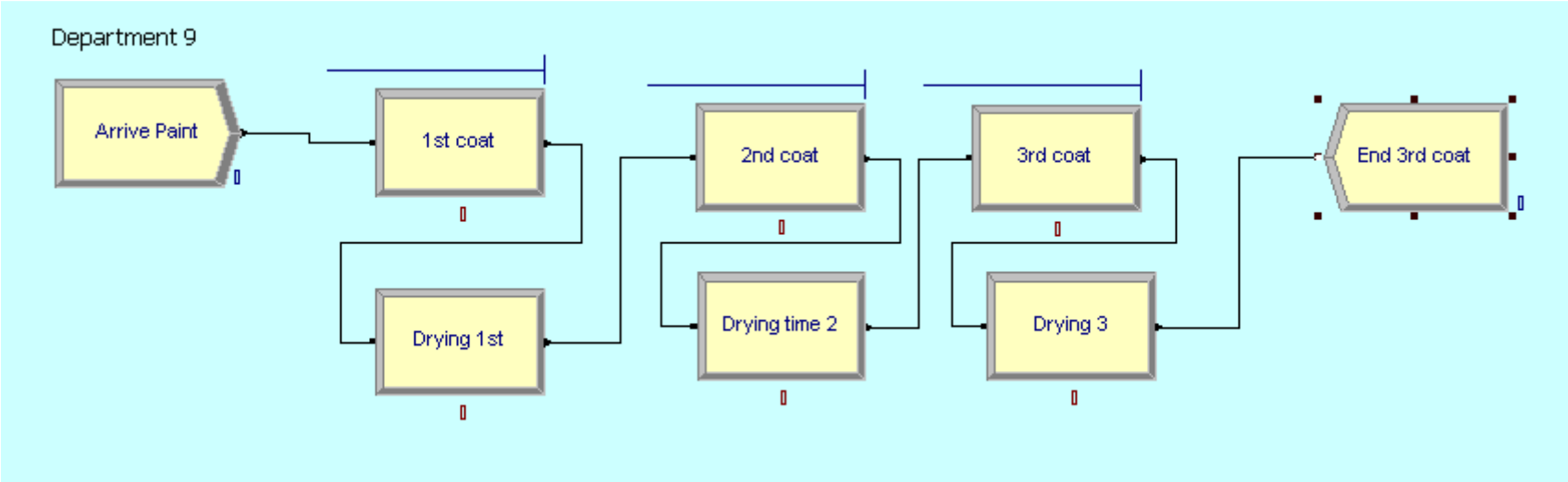
Department 7



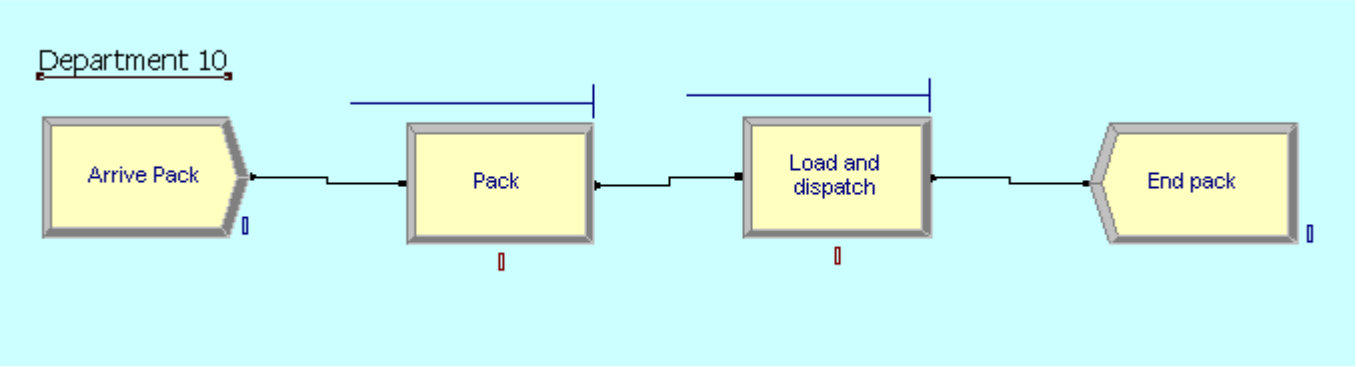
Department 8



Department 9



Department 10



k) Arena reports

Department 1

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Align and Tack Body.Queue	0.00	(Insufficient)	0.00	0.00
Align and Tack Conical.Queue	0.00306995	(Insufficient)	0.00	0.04911920
Conical Rolling.Queue	8.4580	(Insufficient)	0.00	16.4994
Data package.Queue	0.00	(Insufficient)	0.00	0.00
Flame Cutting.Queue	3.8713	(Insufficient)	0.00	10.3802
Guillotining.Queue	25.4897	(Insufficient)	0.00	51.3139
Inspection Stack.Queue	294.67	(Insufficient)	0.00	590.73
Inspection.Queue	0.00	(Insufficient)	0.00	0.00
Offloading and Nibbler.Queue	279.55	(Insufficient)	0.00	555.35
Rolling.Queue	2.5335	(Insufficient)	0.00	6.2303

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Align and Tack Body.Queue	0.00	(Insufficient)	0.00	0.00
Align and Tack Conical.Queue	0.00006735	(Insufficient)	0.00	1.0000
Conical Rolling.Queue	0.1856	(Insufficient)	0.00	4.0000
Data package.Queue	0.00	(Insufficient)	0.00	0.00
Flame Cutting.Queue	0.08493037	(Insufficient)	0.00	3.0000
Guillotining.Queue	1.0485	(Insufficient)	0.00	29.0000
Inspection Stack.Queue	12.1213	(Insufficient)	0.00	30.0000
Inspection.Queue	0.00	(Insufficient)	0.00	0.00
Offloading and Nibbler.Queue	11.4993	(Insufficient)	0.00	28.0000
Rolling.Queue	0.04863425	(Insufficient)	0.00	2.0000

Department 2

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Pipes and Steel.Queue	10.0485	(Insufficient)	0.00	27.5035
Cropping.Queue	927.62	(Insufficient)	0.00	1856.06
Data package.Queue	0.08305222	(Insufficient)	0.00	0.4153
Inspection.Queue	0.00	(Insufficient)	0.00	0.00
Sawing.Queue	627.30	(Insufficient)	0.00	1278.05

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Batch Pipes and Steel.Queue	0.4981	(Insufficient)	0.00	20.0000
Cropping.Queue	24.8284	(Insufficient)	0.00	51.0000
Data package.Queue	0.00020583	(Insufficient)	0.00	1.0000
Inspection.Queue	0.00	(Insufficient)	0.00	0.00
Sawing.Queue	14.3028	(Insufficient)	0.00	43.0000

Department 3

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Conical prep.Queue	1910.16	(Insufficient)	119.64	3476.42
FITUP.Queue	0.00	(Insufficient)	0.00	0.00
NormalPrep.Queue	1524.26	(Insufficient)	243.17	3113.37
Setup and Tag conical.Queue	1766.10	(Insufficient)	379.98	3366.14
Setup and Tag.Queue	0.00	(Insufficient)	0.00	0.00
Weld prep.Queue	1789.07	(Insufficient)	0.00	3232.49

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Conical prep.Queue	4.7142	(Insufficient)	0.00	10.0000
FITUP.Queue	0.00	(Insufficient)	0.00	0.00
NormalPrep.Queue	3.7618	(Insufficient)	0.00	10.0000
Setup and Tag conical.Queue	4.3587	(Insufficient)	0.00	9.0000
Setup and Tag.Queue	0.00	(Insufficient)	0.00	0.00
Weld prep.Queue	4.4154	(Insufficient)	0.00	9.0000

Department 4

CBZ facility simulation

Replications: 1 Time Units: Minutes

Entity

Other

WIP	Average	Half Width	Minimum Value	Maximum Value
Conical	4.4399	(Insufficient)	0.00	9.0000
Rolled	0.5679	(Insufficient)	0.00	3.0000

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Flanges.Queue	0.00	(Insufficient)	0.00	0.00
Manhole prep.Queue	0.00	(Insufficient)	0.00	0.00
Prep for xray.Queue	0.00	(Insufficient)	0.00	0.00
Weld conical section.Queue	44.0809	(Insufficient)	0.00	183.23
Weld rolled section.Queue	88.5440	(Insufficient)	0.00	185.58
Weld sections together.Queue	1404.25	(Insufficient)	0.00	2494.13

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Flanges.Queue	0.00	(Insufficient)	0.00	0.00
Manhole prep.Queue	0.00	(Insufficient)	0.00	0.00
Prep for xray.Queue	0.00	(Insufficient)	0.00	0.00
Weld conical section.Queue	0.08616563	(Insufficient)	0.00	2.0000
Weld rolled section.Queue	0.1731	(Insufficient)	0.00	2.0000
Weld sections together.Queue	2.7449	(Insufficient)	0.00	6.0000

Department 5

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Pressure test.Queue	4.0095	(Insufficient)	0.00	21.0574
Visual inspection.Queue	0.5659	(Insufficient)	0.00	5.6590
XRay.Queue	12.1806	(Insufficient)	0.00	87.1277

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Pressure test.Queue	0.00821465	(Insufficient)	0.00	1.0000
Visual inspection.Queue	0.00115941	(Insufficient)	0.00	1.0000
XRay.Queue	0.02495556	(Insufficient)	0.00	1.0000

Department7

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch valves.Queue	360.57	(Insufficient)	0.00	726.44
Domevalve assembly.Queue	6836.91	(Insufficient)	0.00	13662.41
Pipework assembly.Queue	710.16	(Insufficient)	0.00	1753.57
Remove pipework.Queue	478.45	(Insufficient)	0.00	1992.40
Steelwork.Queue	658.90	(Insufficient)	0.00	1690.67
Vessel assembly.Queue	812.87	(Insufficient)	0.00	2093.26

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Batch valves.Queue	0.4785	(Insufficient)	0.00	2.0000
Domevalve assembly.Queue	9.0734	(Insufficient)	0.00	19.0000
Pipework assembly.Queue	0.4712	(Insufficient)	0.00	3.0000
Remove pipework.Queue	0.3175	(Insufficient)	0.00	3.0000
Steelwork.Queue	0.4372	(Insufficient)	0.00	3.0000
Vessel assembly.Queue	0.5394	(Insufficient)	0.00	4.0000

Department 8

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Sandblasting.Queue	8.9232	(Insufficient)	0.00	45.6927

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Sandblasting.Queue	0.02097590	(Insufficient)	0.00	1.0000

Department 9

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
1st coat.Queue	17.7870	(Insufficient)	0.00	67.6497
2nd coat.Queue	27.0290	(Insufficient)	0.00	69.4367
3rd coat.Queue	27.8154	(Insufficient)	0.00	73.6201

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
1st coat.Queue	0.1483	(Insufficient)	0.00	2.0000
2nd coat.Queue	0.2254	(Insufficient)	0.00	2.0000
3rd coat.Queue	0.2320	(Insufficient)	0.00	2.0000

Department 10

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Load and dispatch.Queue	4.4256	(Insufficient)	0.00	23.1741
Pack.Queue	2.6882	(Insufficient)	0.00	16.5478

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Load and dispatch.Queue	0.05380489	(Insufficient)	0.00	1.0000
Pack.Queue	0.03268290	(Insufficient)	0.00	1.0000

l) Reports of the complete facility simulation

CBZ facility simulation

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Department1 Conical.Queue	884.70	(Insufficient)	0.00	1759.73
Department1 Rolled.Queue	772.18	(Insufficient)	0.00	1550.91
Department10.Queue	0.00	(Insufficient)	0.00	0.00
Department2 Cropping.Queue	699.82	(Insufficient)	0.00	1377.36
Department2 Sawing.Queue	590.88	(Insufficient)	0.00	1181.16
Department3 Conical.Queue	254.69	(Insufficient)	0.00	518.31
Department3 Rolled.Queue	365.81	(Insufficient)	0.00	730.46
Department3.Queue	43.6286	(Insufficient)	0.00	113.28
Department4.Queue	2316.70	(Insufficient)	0.00	4294.39
Department5.Queue	0.00	(Insufficient)	0.00	0.00
Department7.Queue	122.87	(Insufficient)	0.00	514.45
Department8.Queue	0.00	(Insufficient)	0.00	0.00
Department9.Queue	0.00	(Insufficient)	0.00	0.00
Final Test.Queue	0.00	(Insufficient)	0.00	0.00
Load on Trolley.Queue	0.00	(Insufficient)	0.00	0.00
Remove Pipe Work.Queue	201.73	(Insufficient)	0.00	620.52

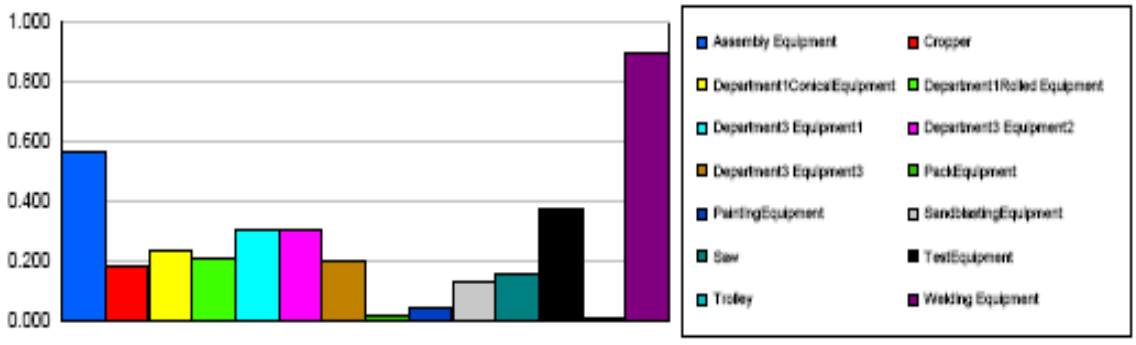
Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Department1 Conical.Queue	2.2135	(Insufficient)	0.00	19.0000
Department1 Rolled.Queue	1.9320	(Insufficient)	0.00	19.0000
Department10.Queue	0.00	(Insufficient)	0.00	0.00
Department2 Cropping.Queue	3.5019	(Insufficient)	0.00	38.0000
Department2 Sawing.Queue	2.9568	(Insufficient)	0.00	38.0000
Department3 Conical.Queue	0.6372	(Insufficient)	0.00	5.0000
Department3 Rolled.Queue	0.9153	(Insufficient)	0.00	7.0000
Department3.Queue	0.2183	(Insufficient)	0.00	3.0000
Department4.Queue	4.3473	(Insufficient)	0.00	9.0000
Department5.Queue	0.00	(Insufficient)	0.00	0.00
Department7.Queue	0.1537	(Insufficient)	0.00	2.0000
Department8.Queue	0.00	(Insufficient)	0.00	0.00
Department9.Queue	0.00	(Insufficient)	0.00	0.00
Final Test.Queue	0.00	(Insufficient)	0.00	0.00
Load on Trolley.Queue	0.00	(Insufficient)	0.00	0.00
Remove Pipe Work.Queue	0.2524	(Insufficient)	0.00	2.0000

CBZ facility simulation

Replications: 1 Time Units: Minutes

Resource

Usage

Scheduled Utilization	Value
Assembly Equipment	0.5609
Cropper	0.1822
Department1ConicalEquipment	0.2349
Department1Rolled Equipment	0.2071
Department3 Equipment1	0.3032
Department3 Equipment2	0.3032
Department3 Equipment3	0.1984
PackEquipment	0.01273844
PaintingEquipment	0.04080241
SandblastingEquipment	0.1302
Saw	0.1560
TestEquipment	0.3737
Trolley	0.00514876
Welding Equipment	0.9004