Chapter 1: Introduction

1.1 Company Background

Euro-Plastifoam (Pty) Ltd is a leading manufacturer of plastic injection moulded parts and polyurethane moulded component trim parts in South Africa. Products that are being manufactured include foam seating, steering wheels, backrests, headrests, telephone handsets, wheelchair tyres and dashboards. Although a very wide range of products are being manufactured, the company's main focus is on plastic injection moulded components for the automotive industry. Customers include companies such as Nissan, BMW, Faurecia, Lear Corporation, Automotive Leather Company and Ford.

Euro-Plastifoam is situated in Rosslyn, one of Pretoria's industrial areas.

The company was founded in 1971, under the name Magnus Industries (PTY) LTD, by the two current directors of the company, both Italians, Mr Stefano Bazzini and Mr Pierro Ceccareli.

What started out as a small company in the 1970's soon grew into an advanced and leading manufacturer in its field.

About 300 people are employed by Euro-Plastifoam, and the modern production facility of about 30 000 m^2 has some of the most sophisticated production equipment available.

A second plant was recently built, situated also in Rosslyn, and focusing only on polyurethane moulded parts.

The quality of the products Euro-Plastifoam produce is of such high standard that many are found in Europe, Japan and beyond. The group also has technical agreements and joint ventures with leading European companies.

1.2 Problem Definition

Euro-Plastifoam was recently chosen as the national supplier of over fifty different injection moulded trim components for the latest model Ford Ranger truck in the T6 Program. This will result in the normal daily production of Euro-Plastifoam being tripled. It is crucial for the success of the company to ensure the production process flow in the Injection Moulding Plant is optimised, and that all waste in the value chain is eliminated.

1.3 Project Aim

The aim of this project is to significantly improve the production process in the plastic injection moulding value chain at Euro-Plastifoam in order to meet the high production demand.

1.4 Project Scope

The scope of this project will cover the entire injection moulding value chain internal to Euro-Plastifoam. General production flow will be analysed, from raw material being received to the finished product being dispatched.

The production process will be optimized by taking into account the following:

- Analysis of the raw materials receiving dock.
- Efficiency and effectiveness of material handling equipment currently used.
- Improvement of the current state value stream.
- Warehousing capacity requirements for the T6 Program.
- Analysis of the dispatch area

Exclusions to the Project Scope:

- Any production taking place at Plant 2, Euro-Plastifoam's polyurethane plant.
- External operations i.e. other members of the supply chain.

The primary focus will be on those parts produced for the T6 Program.

1.5 Project Objectives and Deliverables

The main deliverable of this project is an improved – and ultimately optimised – injection moulding value stream. In order to achieve this, a number of deliverables will have to be met, including:

- A comprehensive study on existing literature of relative methods, tools and techniques applied in the past in similar scenarios.
- A thorough analysis of the current state value stream.
- An improved future state value stream, that will be the result of various Industrial Engineering principles applied. These principles will be decided on after completion of the literature study, and may include the introduction of a Kanban communication system, Just-In-Time, Facilities Planning, Lean Manufacturing, and 5S Housekeeping.
- A sustainable, detailed improvement plan.

Optimisation will be achieved through the identification and application of the appropriate Industrial Engineering methods, tools and techniques. For this project to be a success a definite improvement in the production process flow must be clearly visible. The methods, tools and techniques applied must not be a temporary solution; it should rather be sustainable in the long run.

1.6 Project Overview

Chapter 2 presents the findings from a wide range of literature studied which can be applicable to solve the problem at hand. Different Industrial Engineering methods, tools and techniques are identified and analysed. Chapter 3 continues with the selection and discussion of the chosen solution approaches and how they will be applied to solve the specified problem. Chapter 4 presents the development of a supplementary method which can be used to determine the efficiency in the injection moulding manufacturing process. In Chapter 5 the data collection process is discussed, and in Chapter 6 the collected data is analysed. Chapter 7 is an in-depth presentation of the design and development phase of this project. In Chapter 8 all recommendations are discussed, after which this project is concluded.

Chapter 2: Literature Review

From the various literature studied, many appropriate methods, tools and techniques were identified that can be used to improve and optimise the production process flow at Euro-Plastifoam. These include the application of lean manufacturing tools such as Value Stream Mapping, Just-In-Time (JIT), Single Minute Exchange of Die (SMED), 5S House Keeping and the Concept of Kanban. Other methods, tools and techniques identified that can be applied effectively are Supply Chain Management, Facilities Planning and Simulation Modeling.

2.1 Lean Manufacturing

By definition, lean manufacturing is an organised approach to detecting and removing all non-value added activities through the continuous improvement of the entire supply chain (Willhite, 2004), and the term "Lean" is described by Wu and Wee (2009) as a series of activities and solutions to reduce Non-Value Added operations, eliminate waste, and improve the Value Added processes.

Harris (2004) feels it is essential for every manufacturer to take the Lean approach, and implement it in the organisation as a strategic plan and not as an isolated strategy. Aulakh and Gill (2008) warns that the main reason why many organisations fail in their road to lean manufacturing is the lack of understanding the big picture, the guiding principles, over emphasis on tools of lean manufacturing, and also organisational ill preparedness.

The first step towards going lean must be the understanding of all current processes. The key is to be interested in what actually happens on the manufacturing floor, rather than what is supposed to happen (Makeham, 2002). At the core of lean manufacturing lies Lean thinking. This customer-focused process requires everyone in the organisation to continuously eliminate waste (Aulakh and Gill, 2008).

Chitturi (2010) identifies the five fundamental lean principles to be:

1. The specification of value from the customer's point of view.
2. Identification of the value stream.
3. Making the identified value flow.
4. Setting the pull system, which means only to manufacture as needed.

5. Perfection in producing exactly what the customer requires, exactly by when it's required, and of course in the right quantity with minimum waste.

Aulakh and Gill (2008) recommend that an organisation should follow the following practices in order to transform lean principles into actions to achieve lean thinking:

- Ensure uninterrupted flow of information
- Synchronise flow throughout the value stream
- Strive for perfect quality
- Pursue an adaptive product development process
- Nurture organisational learning
- Optimise the capabilities and utilisation of all people
- Promote leadership and effective decision making at all levels

Within Japanese production systems many tools for lean manufacturing were developed, including Value Stream Mapping, JIT, SMED and Kanban which will be discussed in the following sections (Braiden and Herron, 2007).

2.2 Value Stream Mapping

Value Stream Mapping (VSM) is a lean manufacturing tool developed by Toyota (Steinlicht, et al., 2010) and was traditionally used for the quick analyses of product flow through a manufacturing system, from raw material to delivery (Gullander and Solding, 2009).

VSM is defined by Pan, Feng, and Jiang (2010) as a technique to help you better understand, analyse and streamline any production process. The production process path is visualised by graphically mapping the current state value stream.

The aim and ultimate goal of VSM is to identify all areas of waste in the manufacturing process and find solutions how the identified waste can be eliminated from the value stream (Baglee and Melvin, 2008).

The Value Stream is defined as all the actions, both value-adding and non-value-adding, that is required to complete a product or service from beginning to end (Pan, Feng, and Jiang, 2010).

Mujtaba and Petersen (2010) comment that VSM is a tool used to uncover and eliminate waste. They further explain that the concept of waste is fundamental to lean thinking, and also that any efforts to systematically reduce and eliminate waste in a manufacturing process can help to reduce lead time and improve customer satisfaction.

Definition of waste

Waste is any activity that consumes time, resources, or space but does not add value to the product as perceived by the customer. It is also suggested that the 'waste' concept is at the center of the lean philosophy (Mujtaba and Petersen, 2010).

Pan, Feng, and Jiang (2010) proved Value Stream Mapping to be a very useful technique in reducing production costs and shortening delivery time, and emphasises that in order to guarantee on-time delivery and to meet the customer's expectations, it is vital that an efficient production process is coupled with reasonable quality control.

Benefits of Value Stream Mapping:

The following benefits have been outlined by Pan, Feng, and Jiang (2010), Mujtaba and Petersen (2010), as well as by Baglee and Melvin (2008).

- The visualisation of material and associated information flow
- The identification of wasted efforts and practices
- Provides managers with the ability to step back and rethink their entire development process from a value creation perspective
- Improving all processes from a system's perspective
- When applied appropriately, VSM can help the manufacturing industry eliminate waste, improve product quality, maintain better inventory control, and obtain better financial and operational control
- Prioritising activities to reach the future state goal
- Helps to uncover bottlenecks in a process that prevents it from flowing at its optimum.

In order to use Value Stream Mapping as a tool, Baglee and Melvin (2008) advise to firstly define the value of each process and also how it relates to the product. Secondly, the identification of the resources and activities required to manufacture and deliver the product is very important (including an identification of the key suppliers). Finally the non-value-adding activities must be identified and suggestions should be made be made on how to reduce waste.

Baglee and Melvin (2008) also state that non-value-adding activities may include waiting time, inappropriate processing, unnecessary movement, and overproduction.

Pan, Feng, and Jiang (2010) describe the typical steps in the Value Stream Mapping process to be as follow:

Step 1: Determining the Value Stream

It's advised that this technique is applied best if a specific order is tracked (preferably a medium-sized order), data collected and analysed through the entire production cycle. It therefore makes it easier to determine the exact Value Stream to be improved, and also eliminate the extensive scoping efforts necessary to determine the practical limits of the mapping activity.

Step 2: Creating a current state Value Stream Map

Standardised graphical tools and notations must be used to depict the "as-is" condition, including a display of all the problems, wastes, inefficiencies and flaws. It's critical for the success of this technique for this to be a brutally honest depiction. In addition, Mujtaba and Petersen (2010) found that, in general, the biggest loopbacks or delays in a value stream provide the biggest opportunity for improving the process capability.

Step 3: Creating a future state Value Stream Map

In order to create the future state Value Stream Map, much attention must be given to improving the general flow, reducing non-value-adding activities, and ensuring that customer's requirements are met. Also included must be the necessary process improvements to achieve the future state vision. Steinlicht, et al. (2010) describes a future state map as a representation of an ideal system that serves as a means to develop improvement goals for the project team, and also meets the customer's needs.

Step 4: Making an improvement plan

The final step in this process is to develop a detailed improvement plan.

According to Pan, Feng, and Jiang (2010), the mapping activity is simply a tool. It is the implementation of the improvement plan that is the key to success.

Steinlicht, et al. (2010) advises that in order to reach the improvement goals, it is very important to understand exactly how outcomes are currently being delivered, and to identify the gaps between the current state and the future state.

Mujtaba and Petersen (2010) recommend using the following Value Stream Mapping measurements:

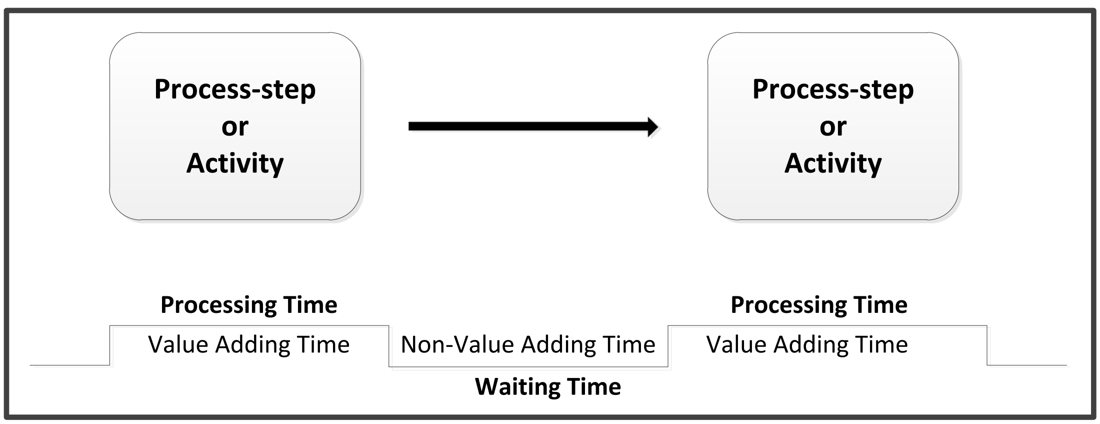
Lead Time (LT): The average time it takes for one request to go through the entire process from start to finish, including all waiting times/queuing between sub-processes.

Queue Time (QT): The average time between sub-processes that the request is idle.

Processing Time (PT): The average time the request is being worked on.

Standard Value Stream Mapping notation, as suggested by Mujtaba and Petersen (2010).

Figure 1: Standard Value Stream Mapping notation



Data collection

Mujtaba and Petersen (2010) suggest the following methods of data collection for the use in Value Stream Analysis:

- Document analysis
- Extraction of phase times from a requirements tracking tool
- Quantitative analysis of historical data
- Interviews with key individuals in the production process, and also gathering solution proposals for waste reduction with the focus on reducing the total lead time.

2.3 Just-In-Time (JIT)

A JIT production system is described by Constable and Demmy (1988) firstly as a philosophy of management. It is said that this philosophy highlights the reduction of waste and the active participation of all employees in the continuing improvement of the firm's products and processes. Secondly, JIT is a set of techniques applied by the production management. These techniques frequently provide substantial cost reductions, while concurrently improving quality, throughput, and flexibility.

Duimering and Safayeni (1991) explain that, in essence, JIT focuses on creating a manufacturing system capable of operating with very low levels of raw materials, work-in-progress, and finished goods inventory.

Maxim, et al. (2009) states that the goal of JIT is to quicken turnaround time whilst keeping inventory low.

In their research to optimise the batch manufacturing system layout concept, Harrison, Leonard, and Wainwright (1992) identified the following benefits of JIT:

- Reduction of Work In Progress
- Reduction of raw material and finished parts
- Reduction of floor space requirements
- Reduction in overheads
- Increased quality
- Increased flexibility
- Increased productivity

Constable and Demmy (1988) found that major opportunity areas for the application of JIT include work methods, quality assurance, supplier relationships, physical layout, and production scheduling and control.

2.4 Single Minute Exchange of Die (SMED)

When a company is working with single piece batch size, it is very important to have near zero set up time in order to achieve maximum utilisation of resources as well as flexibility.

Aulakh and Gill (2008) define SMED as the method of changing the setup of a process from one product type to another in minimal time.

2.5 The Concept of Kanban

Kanban is defined as a method for maintaining an orderly flow of material (Aulakh and Gill, 2008). Kanban cards are used to indicate material order points, quantity of material required, from where the material is ordered, and to where it should be delivered.

Farahmand and Heemsbergen (1994) confirm that the Kanban inventory control system is the type of system most often used as a production scheduling technique for a JIT system.

2.6 5S Housekeeping

This Lean manufacturing tool is a systematic method for standardising and organising the workplace, and Aulakh and Gill (2008) state that it is one of the simplest Lean tools to implement. They also found that 5S house keeping provides immediate return on investment, is applicable to every function in the organisation, and crosses all industry borders.

The 5S's:

1. Sort (sometimes referred to as "Set")
2. Straighten (sometimes referred to as "Sort")
3. Shine
4. Standardise
5. Sustain

The high success rate of 5S, viewed at <http://www.six-sigma-material.com/5S.html>, is due to its simplicity, quick impact, ease of understanding, and universal applications. Also, 5S is frequently one of the elements in every Kaizen event.

For 5S to be a success, a continuous auditing system must be in place. Each of the 5 S's must be assessed. According to Six-sigma-material the following criteria must be used as guidelines in the audit:

The scores are subjectively rated from 0 to 5 as whole numbers with the following criteria as a guide.

0: zero effort, no evidence, not started
1: activity started with minimal effort but not sustainable
2: widespread activity with more opportunity for improvement
3: minimum acceptable level sustained for a month
4: all encompassing activity and sustained for over a month
5: best in class and sustained for at least six months

For ease of understanding, the results can be graphically represented, as showed in Figure 2 and 3.

Figure 2: Example of a 5S Scoring Results Radar Chart

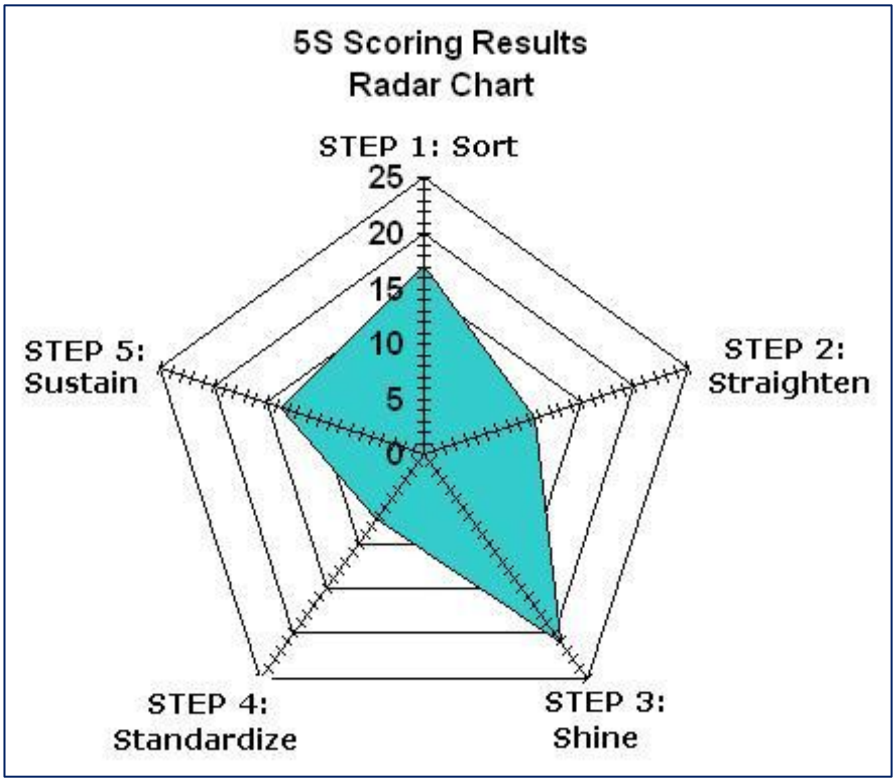
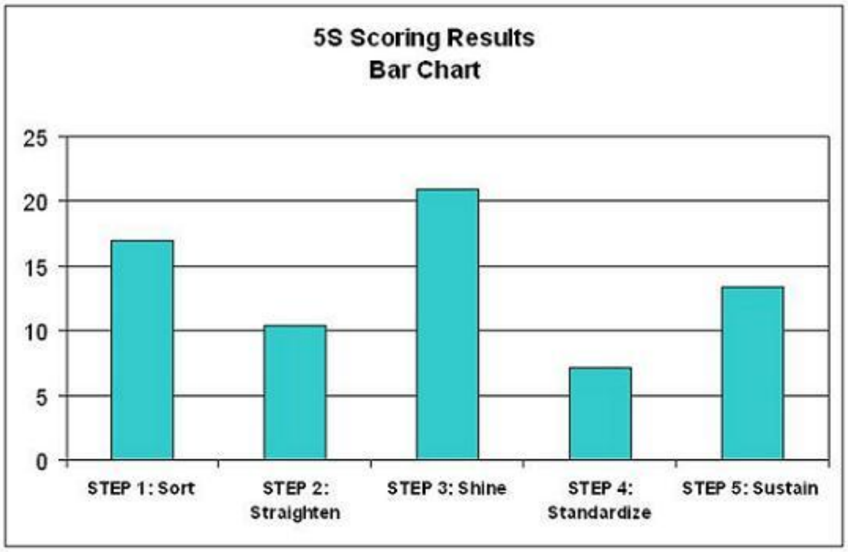


Figure 3: Example of a 5S Scoring Results Bar Chart



2.7 Supply Chain Management

The supply chain has been defined by Baglee and Melvin (2008) as a system whose fundamental parts is linked together and includes raw material suppliers, production facilities, distribution services and customers. They are linked together via the feedback of information and the feed forward flow of materials.

The supply chain is dynamic and involves the constant flow of products, information and funds between different stages in the chain (Baglee and Melvin, 2008). The stages include a variety of customers, manufacturers, retailers, wholesalers, distributors and raw material suppliers.

2.8 Facilities Planning

Facility design can become a very complicated process that requires the management of many conflicting factors, such as material handling automation, process reliability, upgrading capability, cycle time reduction and also investment capital. Wu, et al. (2003) advise that in order to minimise the initial capital investment, it is crucial to balance the capability and capacity factors during the initial stages of facility planning. This will also have a major effect on operating costs later on.

Wu, et al. (2003) identifies the following approaches to facility planning:

Experiential – Refers to experience-based planning and it's an approach that requires past experience and instinct. This is method therefore has obvious limitations.

Master building or Cloning – As the name suggests, this approach is aimed at duplicating whole or part of pre-designed facilities.

Bottom-up and Strategic – These two planning methodologies are opposite in nature. Bottom-up are done from bottom to the top, while the Strategic planning methodology approach the problem from top to bottom. Both methods require very detailed information and tedious procedures.

Systematic Layout Planning – Procedures, phases and conventions are used to help the planners know what to do each step of the way. Layout planning is provided with system and structure, and this saves time and effort.

2.9 Discrete Event Simulation

In modern times computer simulation is a popular tool that can be applied to a wide range of areas, including manufacturing, the military, agriculture, ergonomics and logistics.

Gullander and Solding (2009) define simulation as the process of designing a model of a current, real life system and conducting various experiments. Discrete Event Simulation (DES) has to do with the flow of parts in system.

In their research on simulation and its comparison to Value Stream Mapping, Baglee and Melvin (2008) found the following strengths and weaknesses with simulation:

Strengths

- Can analyse a time span and not only a snapshot
- Not only a rough simplification
- Possible to experiment with system changes and parameters
- The flow of all products can be included in the model

- Dynamic courses of events like complex planning and control logic, and also variations and breakdowns can be included.

Weaknesses

- Demands a large investment in time and money
- Difficulty of getting the right amount of data in the right format
- A good knowledge of simulation methods and programs are needed.
- Often a simulation expert running a simulation project is not otherwise directly involved in the studied system

2.10 Work Measurement

For a process to become lean work measurement is a very important aspect. According to Gagnon (2000), work measurement is the careful analysis of a task, the methods used in its performance, its size, and its efficiency. Work measurement is a helpful tool to determine the time spent to perform a process and offers a comparable, consistent methodology to establish labor capacities.

Gagnon (2000) also comments that the objective of work measurement is to determine the number of workers needed to perform a given task efficiently, the workload in an operation and the time that is required.

In essence, work measurement is to set time standards for a process.

According to Aquillano, Chase and Jacobs (2004), such time standards exist for the following reasons:

- To allocate capacity and schedule work
- To set a benchmark for improvement
- For measuring worker’s performance and set a basis for motivating the workforce

2.11 Problem Identification Methods

There exists many different methods of identifying and analysing a problem, and determining what the exact causes of the problem is. Before one can attempt to solve a certain problem, one first needs to determine exactly what the causes of this problem are. Below a few problem identification methods are discussed.

2.11.1 Cause-and-Effect Analysis

Cause-and-Effect Analysis is performed with the help of a Fishbone diagram, developed in the early 1950's by Professor Kaoru Ishikawa of Tokyo University while working on a quality control project. According to Freivalds (2003) the purpose of the Fishbone diagram is to identify the causes to a problem. This diagram resembles the bones of a fish. The head of the fish is labeled with the effect/problem, while the major bones are usually labeled with factors like man, machine, material and methods. The Fishbone diagram provides support to only focus on the most important sources or causes of a problem.

2.11.2 Critical Analysis Technique

Sugiyama (1989) states that the Critical Analysis Technique is a very useful tool for developing the complete facts of a situation, and thereafter examines and analyses the reasons for them, in order to understand the situation more concretely.

Abstract arguments can be turned into tangible debates very effectively with the use of the Critical Analysis Technique.

In Table 2 a critical analysis template is given that will assist in problem identification. Some questions will be answered by the analyst regarding certain operations, and it's required from the analyst to consistently identify and evaluate alternatives.

Table 1: Critical Analysis Technique

PRESENT METHOD		ALTERNATIVES	SELECTED ALTERNATIVE
Purpose – What is achieved?	Is it necessary? If yes, why?	What else could be done?	What?
Means - How is it done?	Why that way?	How else could it be done?	How?
Place - Where is it done?	Why there?	Where else could it be done?	Where?
Sequence - When is it done?	Why then?	When else could it be done?	When?
Person - Who does it?	Why that person?	Who else could do it?	Who?

2.11.3 Pareto Chart

A Pareto chart helps with the break down of a problem into the relative contributions of its elements. These charts are grounded on the common practical outcome that a large percentage of problems are due to a small percentage of causes, better known as the *80-20 Rule.* This rule is stating that 80% of the problems are caused by 20% of the contributing factors.

The purpose of a Pareto chart is to separate the “vital few from the trivial many.” This allows the analyst to focus only on the few factors that causes the most problems.

This ensures that resources are allocated to the most significant areas.

2.12 Layout Analysis Techniques

According to Freivalds (2003) transport is one of the most noticeable wastes that occur in daily production. The layout of the facility plays an essential role in decreasing transport waste; therefore the optimum layout should yield the lowest level of material handling.

Meyers (1993) argues that if material flow is improved, production costs will automatically be reduced. In order to improve material flow, the following guidelines can be very helpful:

- Eliminating phases in the process
- Combining phases in the process
- Simplifying the operation by the automation of movements between phases.
- Changing the sequence of the process to reduce time and distances.

2.12.1 Process Flow Diagram

Freivalds (2003) states that the Process Flow Diagram is a graphic depiction of the layout of buildings and floors, displaying the positions of the activities on the flow process chart. The flow direction is showed by placing small arrows intermittently along the flow lines. The Process Flow Diagram shows the relationships between key elements in the system. It is a helpful enhancement to the Flow Process Chart because it specifies backtracking and it aids the development of an ideal plant layout.

2.12.2 Flow Process Chart

Syque (2011) defines a Flow Process Chart is simple half-graphical, half-text method used for depicting the sequence of the product flow or procedure. This chart is effective in recording hidden non-production costs. A set of standard process chart symbols (ASME, 1974) must be used to create the Process Flow Chart. A very valuable feature of this chart is that it can be drawn up while the process is taking place. Details regarding flow process charts can be viewed at <http://syque.com/quality_tools/tools/Tools30.htm>.

2.12.3 From-To Chart

Freivalds (2003) suggests that From-To Charts can be very helpful in analysing problems related to the arrangement of departments relative to each other. The 'From-To Chart' depicts the magnitude of material handling taking place between facilities per time period.

An example of a from-to-chart, as depicted in figure 4, can also be found on <http://syque.com/improvement/Travel%20Chart.htm>.

Figure 4: Example of a From-To Chart

Count of occurrence — *Distance between places*

Visits in 1 week

		To: Accounts	Goods in	Stores	Production	Total Visits	Total Distance
From	Accounts		112	120	90	13	1296
	Goods In	112		15	18	9	632
	Stores	120	15		12	3	150
	Production	90	18	12		12	318
Total	Visits	8	8	9	12	37	
	Distance	860	420	324	792		2396

2.12.4 Spaghetti Diagram

A Spaghetti Diagram is the simplest Lean Six Sigma tool. It demonstrates the physical flow of a process, as well as the related travel distance and travel patterns. To create a Spaghetti diagram is to create a visual representation of the actual flow. Information on spaghetti diagrams can be obtained from <http://www.six-sigma-material.com/Spaghetti-Diagram.html>.

The following steps can be used to analyse the process flow with a Spaghetti diagram:

1. Start recording the processes and ask questions if not clear on the activity.
2. Start at the beginning of the scope, the start of the first process. Use directional arrows for the routes that are traced on the paper.
3. Do not leave out any flow movement even if the paper becomes cluttered and difficult to follow.
4. Record the amount of time at each activity.
5. Show the areas where material are stopped, staged, held, inspected and picked up. Look for point-of-use opportunities for materials, tools, and paperwork.
6. Record the names of those involved, dates, times, and other relevant information.
7. Calculate the distance, times, shift, starts, stops, to provide baseline performance.
8. Create a separate diagram showing the ideal state of flow for each that eliminates as much non-value added tasks as possible. The team should target the ideal state and the Project Manager and Champion should remove obstacles that may prevent this objective.

Chapter 3: Selection of appropriate methods, tools and techniques

Various methods, tools and techniques that can be utilised to improve the production process at Euro-Plastifoam had been discussed in Chapter 2. After careful analysis and inputs from the managers at Euro-Plastifoam, several methods, tools and techniques had been identified that will be used for the purpose of this project.

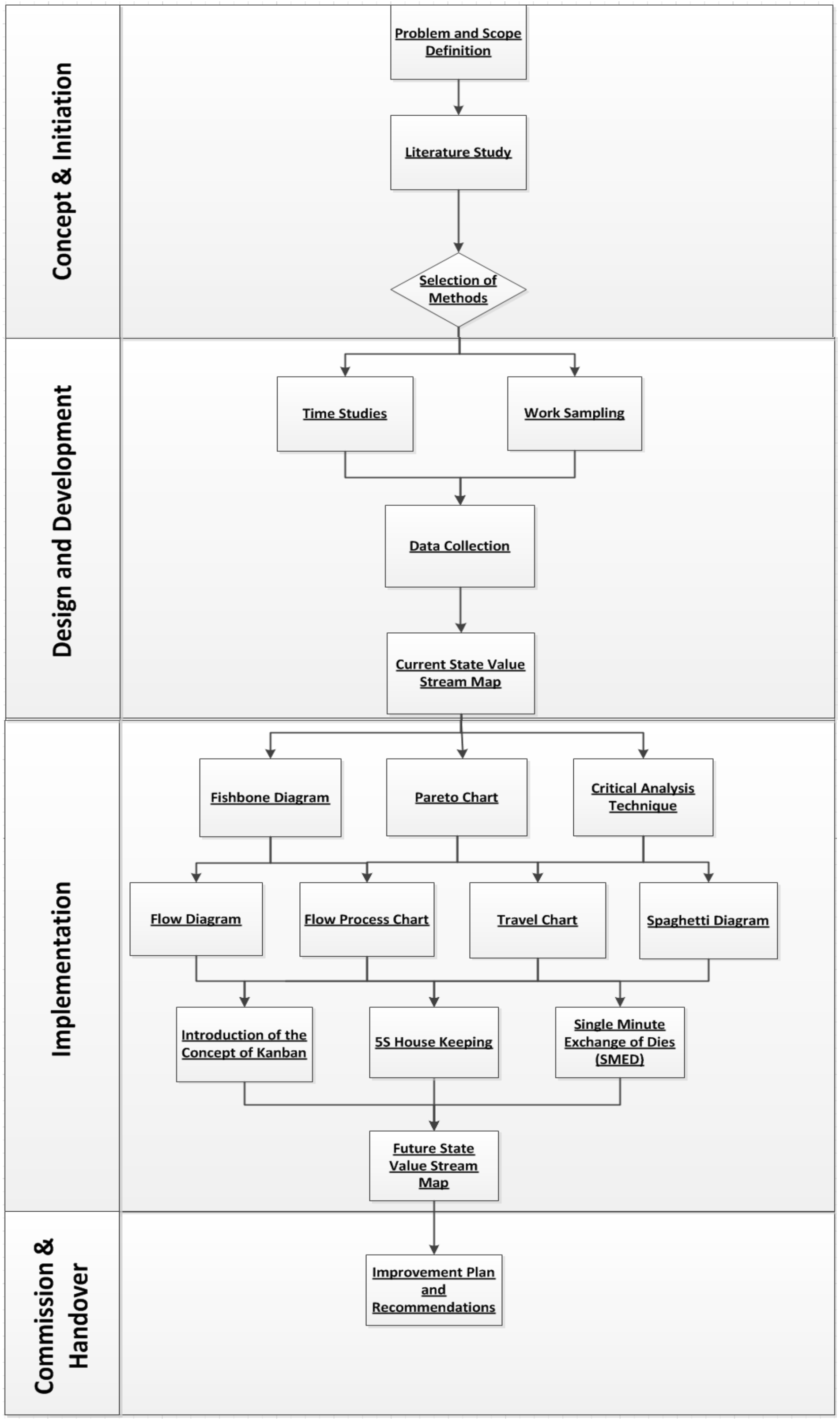
3.1 Selected Methods, Tools and Techniques

- Work Measurement
- Value Stream Mapping
- The Following Problem Identification Methods
    - ❖ Fishbone Diagram
    - ❖ Critical Analysis Technique
    - ❖ Pareto Chart
- Layout Analyses and Improvement
    - ❖ Flow Diagram
    - ❖ From-To Chart (Quantitative Analysis)
    - ❖ Relationship Diagram (Qualitative Analysis)
    - ❖ Flow Process Chart
    - ❖ Spaghetti Diagram
- Introduction of the Concept of Kanban
- 5S Housekeeping
- Single Minute Exchange of Dies (SMED)

The reason why the above-listed methods, tools and techniques were chosen is because they would be best applicable and executable in the production environment of Euro-Plastifoam. Surely some of the other methods described in Chapter 2 will also be applicable, but for the scope of this project only those listed above will be applied.

3.2 Methodology

Figure 5: Methodology



Chapter 4: Development of supplementary methods, tools and techniques

Work measurement techniques such as time studies and work sampling will be utilised in order to get sufficient insight into every aspect of the injection moulding production process, and be able capture an accurate "current state". Complimentary to this, a special chart needs to be developed in order to record the efficiency of the production process and identify critical areas of waste and opportunity for improvement.

With the help and guidance of Mr. Alfonso Yabar - injection moulding specialist and consultant from Faurecia, Spain – it was established that a simple, easy-to-use chart needs to be created for the use of the injection moulding operators while working in the plant. On this chart they need to indicate every problem that occurred during that specific shift and on that specific injection moulding machine. Possible non value-adding time and definite areas of waste are defined in Table 3.

Table 2: Definition of possible areas of waste

Area of waste	Abbreviation that will be used in charts	Definition
Mould Change	MC	Time lost due to another injection moulding tool that has to be inserted into the injection moulding machine.
Warming Up	WU	The time taken for a mould to heat up before production can begin.
No Material	NM	Time lost due to a material shortage, either at the machine or in the raw material store.
No Power	NP	Time wasted due to electricity failures.
No Operator	NO	Production being in an idle state due to no operator being present.
Mould Problem	MoP	No production because of a problem with the mould/injection moulding tool.

Robot Problem	RP	Time wasted due to a problem with the injection moulding robot.
Machine Problem	MaP	Time lost due to an injection moulding machine breakdown or some other machine problem.
Break Time	BT	Production being in an idle state due to operators/personnel being on teatime, lunch or shift change.
Parameter Settings	PS	Time wasted due to experimentation of parameter settings. Incorrect settings because of setters and operators not properly trained results in bad parts being produced.
Packaging Problem	PP	Time lost due to packaging related problems.

The chart also has to have a timeline that will enable us to track the duration of each problem, as described in Table 3.

A template of the efficiency recording chart that was developed can be seen in Figure 6. This chart will be populated by the operator of every injection moulding machine, while that operator is working his/her shift. It is of crucial importance to the accuracy and effectiveness of this study that every operator is properly trained and initiated in the correct way to use this chart. It must also be emphasised to the operators involved that the aim of this study is not to get anyone into trouble or measure anyone’s job performance, but merely to identify areas of improvement in the process.

Figure 6: Efficiency Recording Sheet

EURO-PLASTIFOAM (PTY) LTD

Efficiency Recording Sheet

				Shot counter	
				Start	**End**
Machine Number		**Date**			
Product Reference		**Shift**			
Mould Number		**Operator Name**		**Good parts**	**Bad parts**
Material Type		**Setter Name**			

Notes:

07h00	08h00	09h00	10h00	11h00	12h00
13h00	14h00	15h00	16h00	17h00	18h00
19h00	20h00	21h00	22h00	23h00	00h00
01h00	02h00	03h00	04h00	05h00	06h00

MaP	Machine Problem	**RP**	Robot Problem	**PP**	Packaging Problem	**PS**	Parameter Setting
MoP	Mould problems	**MC**	Mould Change	**NO**	No Operator	**NP**	No Power
BT	Break Time	**WU**	Warming Up	**NM**	No Material		

Chapter 5: Data Collection

Before any data can be collected, it is very important to firstly understand the exact process flow of an injection moulded product. Because all injection moulded parts produced at Euro-Plastifoam has a fairly similar production process flow, only one part number will be singled out to be used for work measurement and value stream analysis. Our findings will be most applicable if a part number is chosen with a medium-sized call off. The suggested improvements and solutions will then generally be applicable to every other injection moulded part's production process flow as well.

Supplementary to the waste identification and production process improvement in the injection moulding plant, extensive data will be collected that will focus on three injection moulding machines in the plant and will be used to determine the efficiency of each machine. This data will be collected with the use of the Efficiency Recording Chart, as described and developed in Chapter 4 of this project report.

5.1 Determining the production process flow

In order to determine the production process flow of a certain injection moulded part, one needs to familiarise oneself with the plant layout and also spend as much time possible in the plant to get first-hand experience of what is actually happening. The layout of all the sectors is given in Figure 7.

The production process flow for a medium-sized order of part number 7625 was followed, and all relevant data collected and recorded. This is one of the parts produced for the T6 program, and it is supplied directly to Ford. The part's name is the Top Finisher Manual LHD 2x4. It is an interior trim component and is fitted in the turret console of the Ford Ranger. All relevant production information is given in Table 4.

The process flow is graphically depicted in Figure 8 with the use of a Process Flow Chart, and a description for each activity in the process with reference to the Process Flow Chart is given in Table 5.

Table 3: Production information for Top Finisher Manual LHD 2x4.

Part Name:	Top Finisher Manual LHD 2x4
Part Number:	7625
Part Weight:	0.281 kg
Part Dimension:	488 x 252 x 116 mm
Number of Clips to be fitted:	7 Clips
Call-off:	1910 parts weekly
Tool ID:	AB39-21045B44
Tool Weight:	2100 kg
Number of Cavities:	1 Cavity
Injection Moulding Machine:	400T
Material Type:	P/E-MD15UV Hostacom CR250F/M
Material Colour:	Ebony
Colour Code:	ZHE
Cycle Time:	40 seconds
Checking Fixture ID:	AB39-21045B44-B-PIA-02_REV46_TOP_FINISHER_MANUAL_P375LHD
Paint:	N/A

Figure 7: Plant Layout

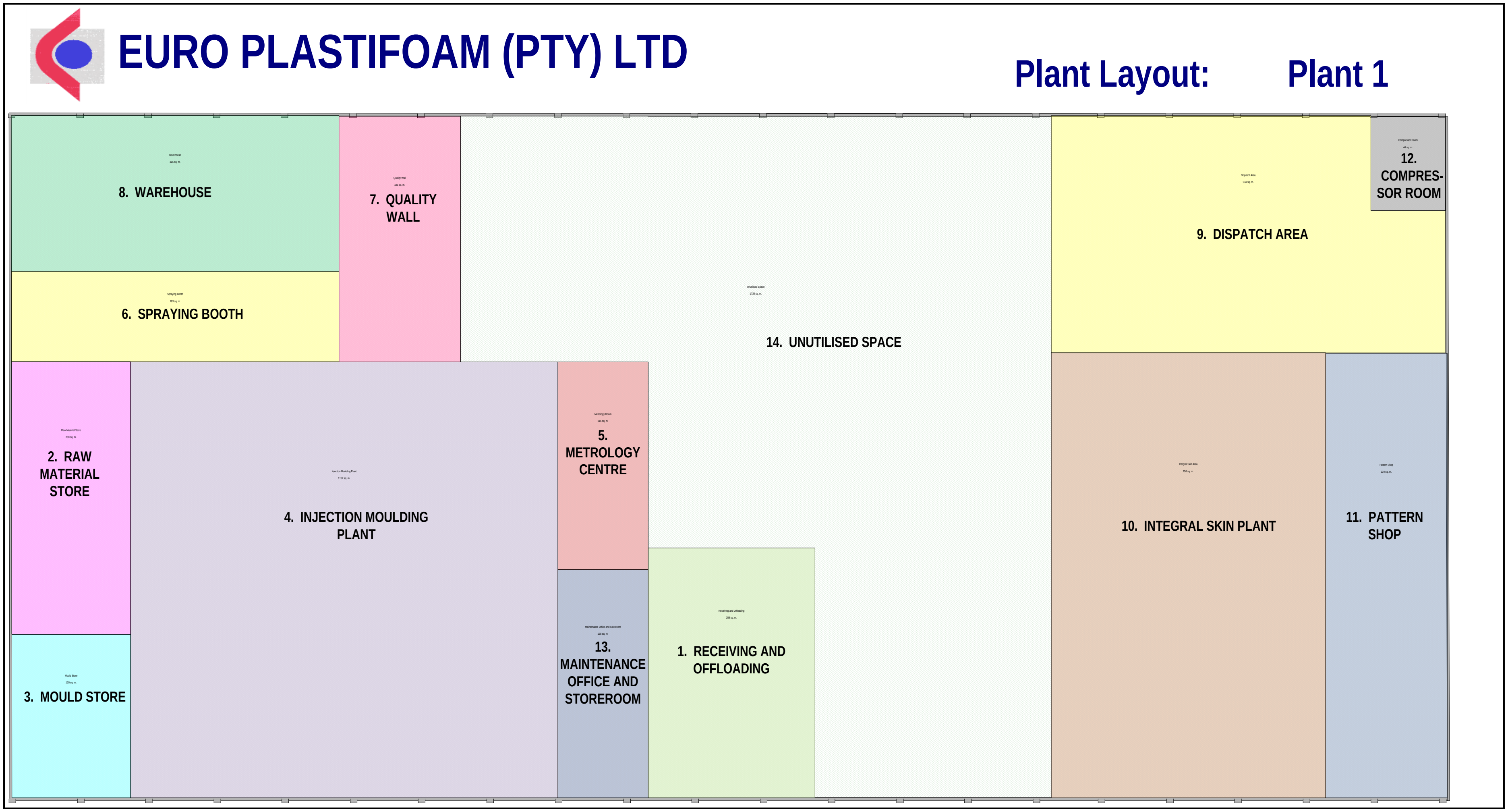


Figure 8: Process Flow Chart – Top Finisher Manual LHD 2x4

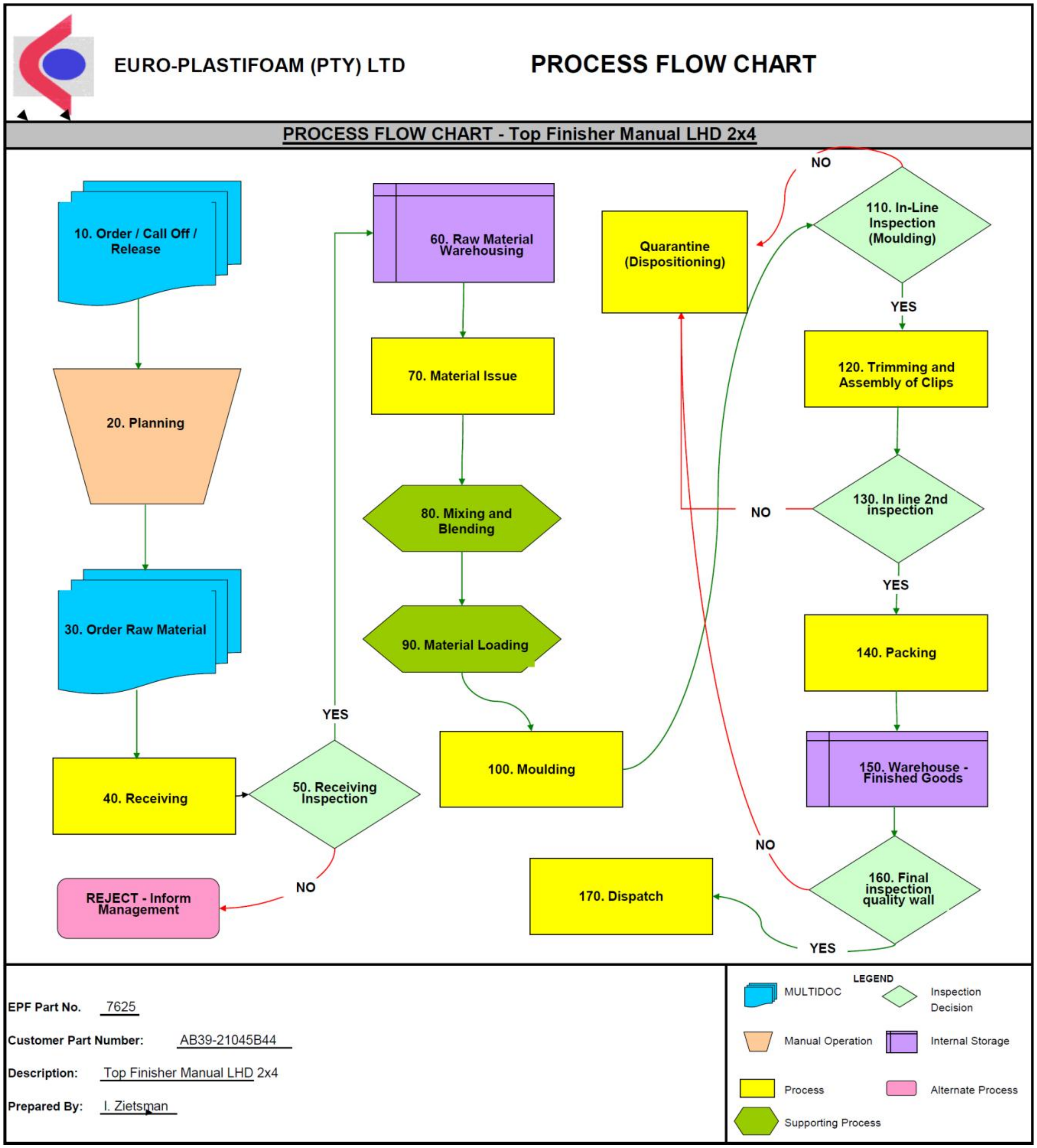


Table 4: Process Description

Process Nr.	Process	Description	Refers to this section in Figure 7
10	Order/Call-off	The call-off for the Top Finisher Manual LHD 2x4 is 1910 parts weekly. That means 382 parts have to be produced daily. This part is delivered directly to Ford, therefore Ford is responsible to provide Euro-Plastifoam with a 3 month forecast of the required quantity of parts.	N/A
20	Planning	Based on the 3 month forecast, as discussed in Process Nr 10 above, the production manager is able to do the production planning. He needs to ensure there will be sufficient capacity, material and resources to deliver the required quantity of parts on time. Euro-Plastifoam does not make use of any planning techniques such as ERP or MRP. This is definitely a technique that can be introduced at Euro-Plastifoam in order to ensure optimal planning and process flow.	N/A
30	Order Raw Material	Although Euro-Plastifoam claims that a JIT manufacturing system is in place, raw material is ordered only once a month. One whole month's worth of material must therefore be kept in the Raw Material Store.	N/A
40	Receiving	Raw material is delivered at the receiving dock. Receiving Manager has to go get the forklift truck, and unload material from delivery truck and place material on a designated area on the floor.	1
50	Receiving Inspection	The Receiving Manager checks if the goods delivered correspond with the delivery note, and if it is in an undamaged state. If so, the Receiving Manager signs the delivery note, otherwise goods are sent back to the supplier.	1
60	Raw Material Warehousing	The Receiving Manager moves the raw material to the Raw Material Store with the forklift truck. The raw material is signed in on the computer system.	2
70	Material Issue	When instruction is given by the production manager, the required quantity and type of material is issued and moved to the specified injection moulding machine. There is no Kanban system currently in place at Euro-Plastifoam.	2

80	Mixing and Blending	The raw material is mixed and blended manually at the injection moulding machine according to the specified ratio.	4
90	Material Loading	Material is loaded into the machine's hopper.	4
100	Injection Moulding	When the mould has reached the required heat and the correct parameter settings are inserted into the machine's computer, production can begin. Parts are checked for sink marks, flow lines and deformation. If any defects are visible, the parameter settings are adjusted.	4
110	In-line Inspection (Moulding)	All the parts are inspected by the operator on the line as it comes out of the mould.	4
120	Trimming and Assembly	Parts are moved to the trimming tables where any flash and sprues are trimmed, and the parts clips assembled.	4
130	In-line 2nd Inspection	All parts are inspected a second time for any visual defects, clips missing or deformation. A few parts from every batch are placed on the checking fixture and dimensionally validated.	4,5
140	Packing	Parts are wrapped in bubble wrap, and 5 Top Finisher parts are packed in a 1P Trenstar reusable plastic bin. 12 Bins are packed on a steel pallet, to form a handling unit.	4
150	Warehouse – Finished Goods	Handling units containing the finished goods are moved to the warehouse. It is Euro-Plastifoam's policy to keep a 5 day safety stock in the warehouse.	8
160	Final Inspection Quality Wall	Before finished goods are dispatched, it needs to go through the Quality Wall. Here every part is unpacked and unwrapped, and again thoroughly inspected for any visual defects, missing clips or any sign of deformation. Every part is rewrapped in the bubble wrap and repacked in the plastic bin.	7
170	Dispatch	Handling units are moved to dispatch. A barcode scanner is used to scan every packaging unit out before the handling units is loaded onto the collection truck. A delivery note is created, and parts are delivered to the customer.	9

5.2 Work Measurement

Time studies were performed for every activity in the production process of the Top Finisher Manual LHD 2x4, in order to get accurate current state information of the system. This information will be used to perform Value Stream Analysis. The collected current stated information can be seen in Table 6, and the Current State Map can be viewed in Figure 9. This map will be used as baseline for improvements to the production process.

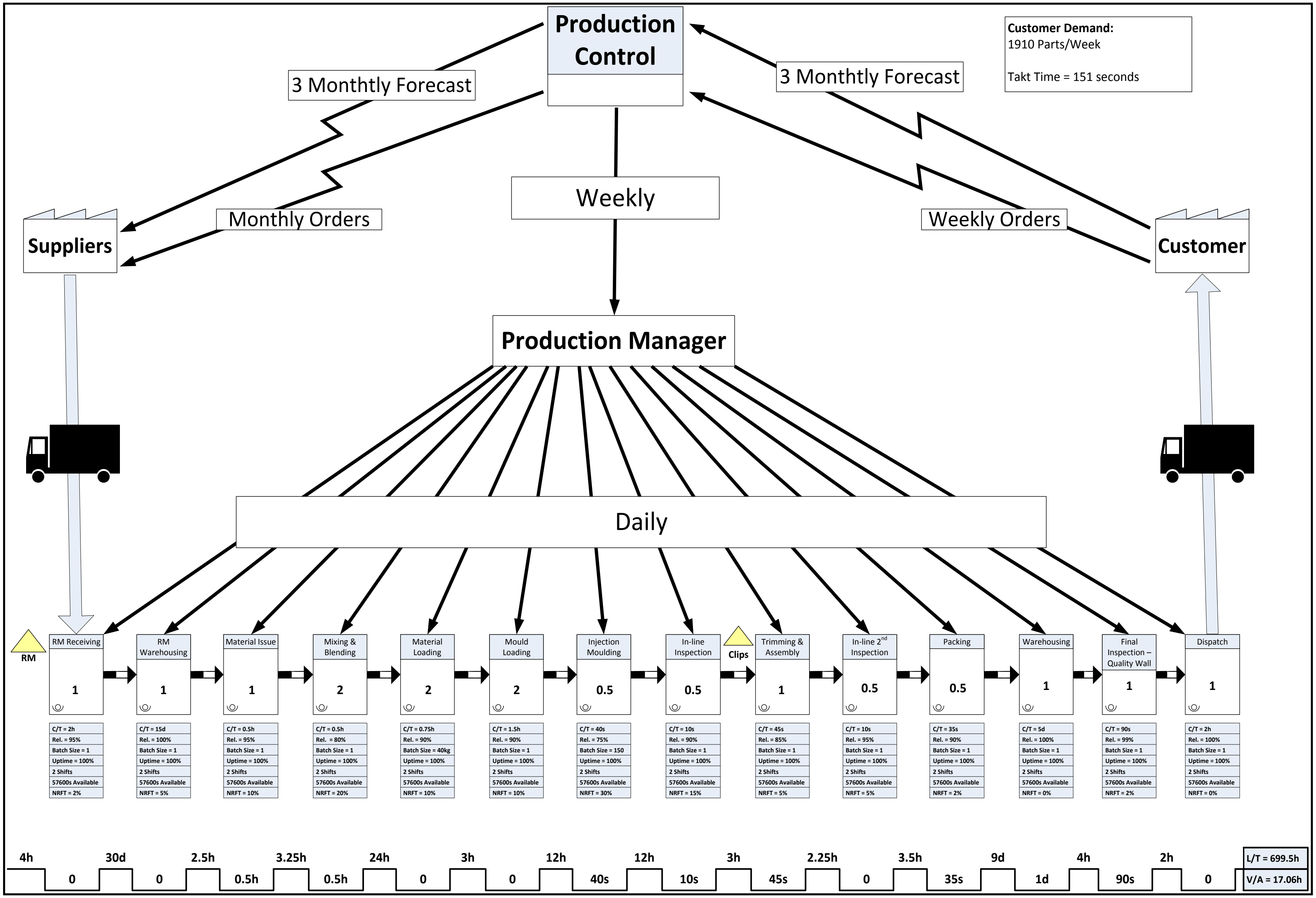
The components to be used in the value stream map are defined by Rother and Shook (1999) as follows:

- Cycle Time (C/T): The time it will take an operator to go through every work element before it is repeated.
- Number of Operators: The number of operators necessary to finish this work element.
- Reliability: The reliability (given as a %) of the output of the cell.
- Not Right First Time (NRFT): The percentage of the product that needs to be reworked, on average, because it does not conform to the customer's specification.
- Value Added Time (VA): The time it takes for this work element to transform the product in such a way that the customer is willing to pay for.
- Lead Time (L/T): The average time it takes for one request to go through the entire process from start to finish, including all waiting times/queuing between sub-processes.

Table 5: Current State Information

Cell	Cycle Time (C/T)	No. of Operators	Reliability	Not Right First Time (NRFT)	Value Added Time (VA)	Lead Time (L/T)
Raw Material Receiving	2h	1	95%	2%	0	4h
Raw Material Warehousing	15d	1	100%	5%	0	30d
Material Issue	0.5h	1	95%	10%	0.5h	2.5h
Mixing and Blending	0.5h	2	80%	20%	0.5h	3.25h
Material Loading	0.75h	2	90%	10%	0	24h
Mould Loading	1.5h	2	90%	10%	0	3h
Injection Moulding	40s	0.5	75%	30%	40s	12h
In-line Inspection	10s	0.5	90%	15%	10s	12h
Trimming and Assembly	45s	1	85%	5%	45s	3h
In-line 2nd Inspection	10s	0.5	95%	5%	0	2.25h
Packing	35s	0.5	90%	2%	35s	3.5h
Warehousing	5d	1	100%	0%	1d	9d
Final Inspection – Quality Wall	90s	1	99%	2%	90s	4h
Dispatch	2h	1	100%	0%	0	2h

Figure 9: Current State Value Stream Map



5.3 Efficiency measurement in the injection moulding plant

A comprehensive study was launched at Euro-Plastifoam to identify any waste and inefficiencies in the production process. As developed and explained in Chapter 4 of this report, the Efficiency Recording Sheet can be used by the operators of the injection moulding machines to record any waste that occurs during production. Data was collected for two complete months; April and May 2011.

This study will focus on three of the most often used injection moulding machines in plant, the 650T, 400T and 250T.

All data was recorded manually by pen and clipboard on the Efficiency Recording Sheet.

To turn this data into valuable information and make it possible to be analysed, every Efficiency Recording Sheet had to be captured in a spread sheet on the computer.

The spread sheet for one day, 1 April 2011, can be viewed in Appendix B.

All the data collected will be analysed in Chapter 6 of this report.

Chapter 6: Data Analysis

Comprehensive data have been collected, as discussed in Chapter 5 of this report. The analysis of this data will be divided into two parts. Firstly, the focus will be on the analysis of the layout and the general process flow. This will be analysed by utilising the Flow Diagram, From-To Chart, Relationship Diagram, Spaghetti Diagram and also the Flow Process Chart. Secondly, the focus will shift to the analysis of the injection moulding efficiency data. In order to analyse this data effectively, we shall firstly make use of Pareto Analysis, followed by a Fishbone Diagram, and also various Bar Graphs and Pie Charts.

The primary aim of the data analysis is to identify areas of waste and inefficiency, and to get a confirmed indication of where valuable improvements can be made.

6.1 Analysis of the plant layout and process flow

From the time studies and other data collected in Chapter 5 of this report, it is clear that a large amount of time is wasted due to material handling and floor layout not being in an optimum state. It is therefore crucial to analyse the layout and the process flow, and to identify possible ways in which the system can be improved.

6.1.1 Receiving of Raw Material

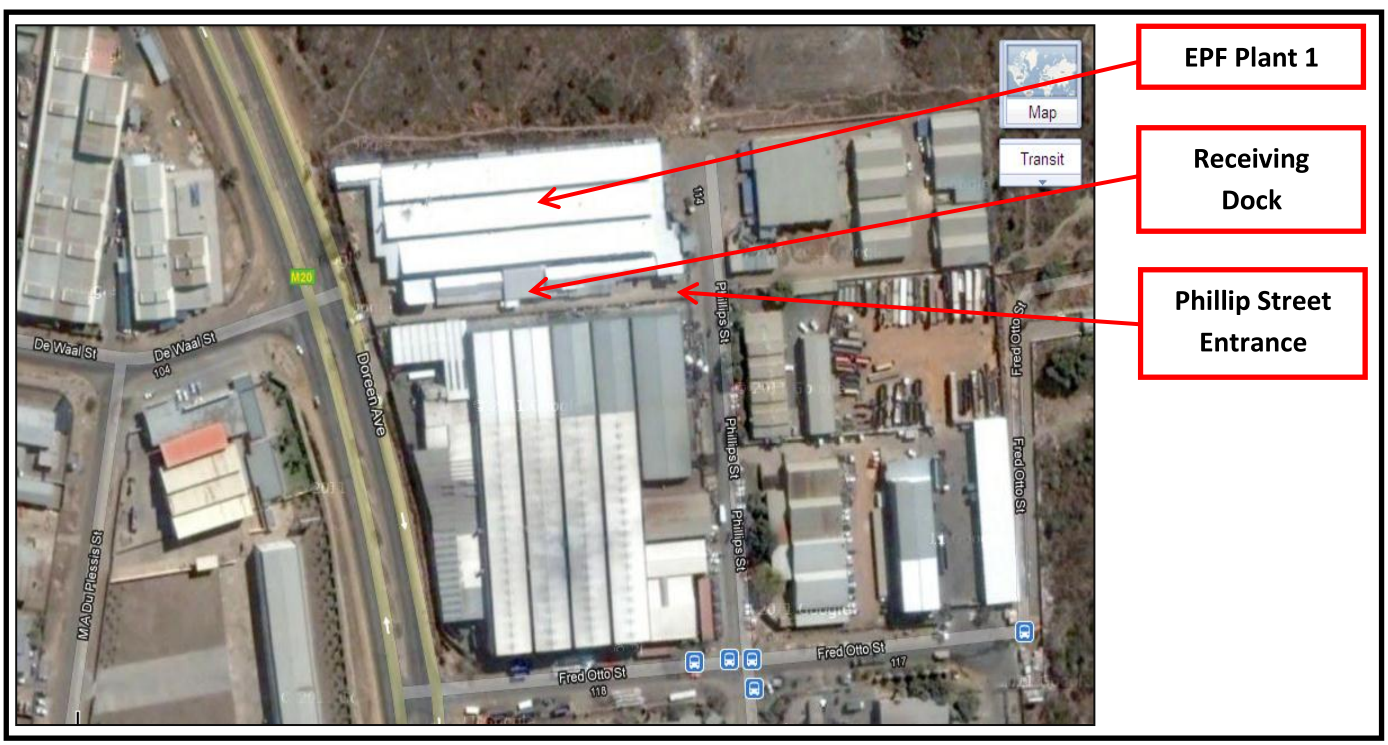
If the forecast for production demand, production planning, and ordering of raw material are not taken into account, since it does not form part of the scope of this project, then the first physical operation taking place at Euro-Plastifoam is the receiving of raw material.

The receiving dock is located at the south side of the facility, as indicated on the satellite photo in Figure 10. Delivery trucks enter the facility from the Phillips Street-entrance. One truck at a time can park at the receiving dock and be unloaded. When unloading is done, the truck has to proceed to the north end of the facilities to turn around and exit at the same entrance used to enter the facilities. This can cause major problems in traffic flow outside the plant, especially if a truck is too big to turn around and has to reverse all the way to the entrance. It often happens that more than one delivery truck arrives at the same time. All of this have a major effect on the logistical flow of the plant, and something should definitely be done to improve the situation.

When the delivery truck arrives at the receiving dock, the receiving manager has to go get the forklift truck to unload the raw material. Since Euro-Plastifoam only has one forklift truck, it is often utilized because of mould changes or movement of finished goods to and from the warehouse. If this is the case then there is an average delay of 13 minutes until unloading of the raw material can begin.

In Figure 11 the flow diagram is shown for the production process of a medium-sized order of Top Finisher Manual LHD 2x4 parts. Raw material is either being delivered in sealed 2 ton octabins, or as a handling unit consisting of fifty 20kg bags sealed onto a pallet. As part of the unloading process, raw material is temporarily placed on a designated area on the floor, as shown by the *number 2* in Figure 11. The distance from the delivery truck to temporary storage area is 13m, as can be seen in Figure 12. On average, the total travelling distance for the forklift truck to unload one shipment of material is 104m. After all material has been unloaded, the receiving manager checks if the delivery corresponds with the delivery note, and whether the goods delivered are in an undamaged state. If everything is in order, the delivery note is signed.

Figure 10: Satellite View



6.1.2 Moving of delivered material to Raw Material Store

The forklift is used to move all delivered material to the raw material store. As can be seen in Figure 12, the From-To Chart, the distance from the temporary storage area to the raw material store is 65m. For an average raw material delivery it will take four trips with the forklift truck to the raw material store to move the entire shipment. That sums to a total travelling distance of 624m just to move the delivered raw material from the delivery truck to the raw material store. This is a definite opportunity for improvement. If raw material can be delivered closer to the raw material store, or if the raw material store can be relocated closer to the receiving area, a considerable amount of time and money could be saved. This idea will be further investigated in Chapter 7 of this report.

6.1.3 Before production begins

When it is time, according to the production schedule, for a certain part to be run on an injection moulding machine, there are a few things that need to be in place before the actual injection moulding can begin. After orders are given by the production manager for the workers to start with a new part, the first thing to be done is to unload the current mould from the relevant injection moulding machine. It has to be taken to the mould store, the correct mould for the newly planned production must be identified, moved to the injection moulding machine and loaded. This mould changing process takes on average a total of 90 minutes to complete. Factors that delay this process are insufficient material handling equipment, and a lack of skilled workers.

The second task to be completed is the issuing of the appropriate raw material from the raw material store. This is done according to the Raw Material Instruction Sheet. The material type, colour, and required quantity are important aspects to consider. Also to be found on the instruction sheet is the mixing and blending information. The appropriate raw material are mixed and blended according to the given ratio. This is done at the injection moulding machine, after which the blended material is loaded into the machine's hopper.

Figure 11: Flow Diagram

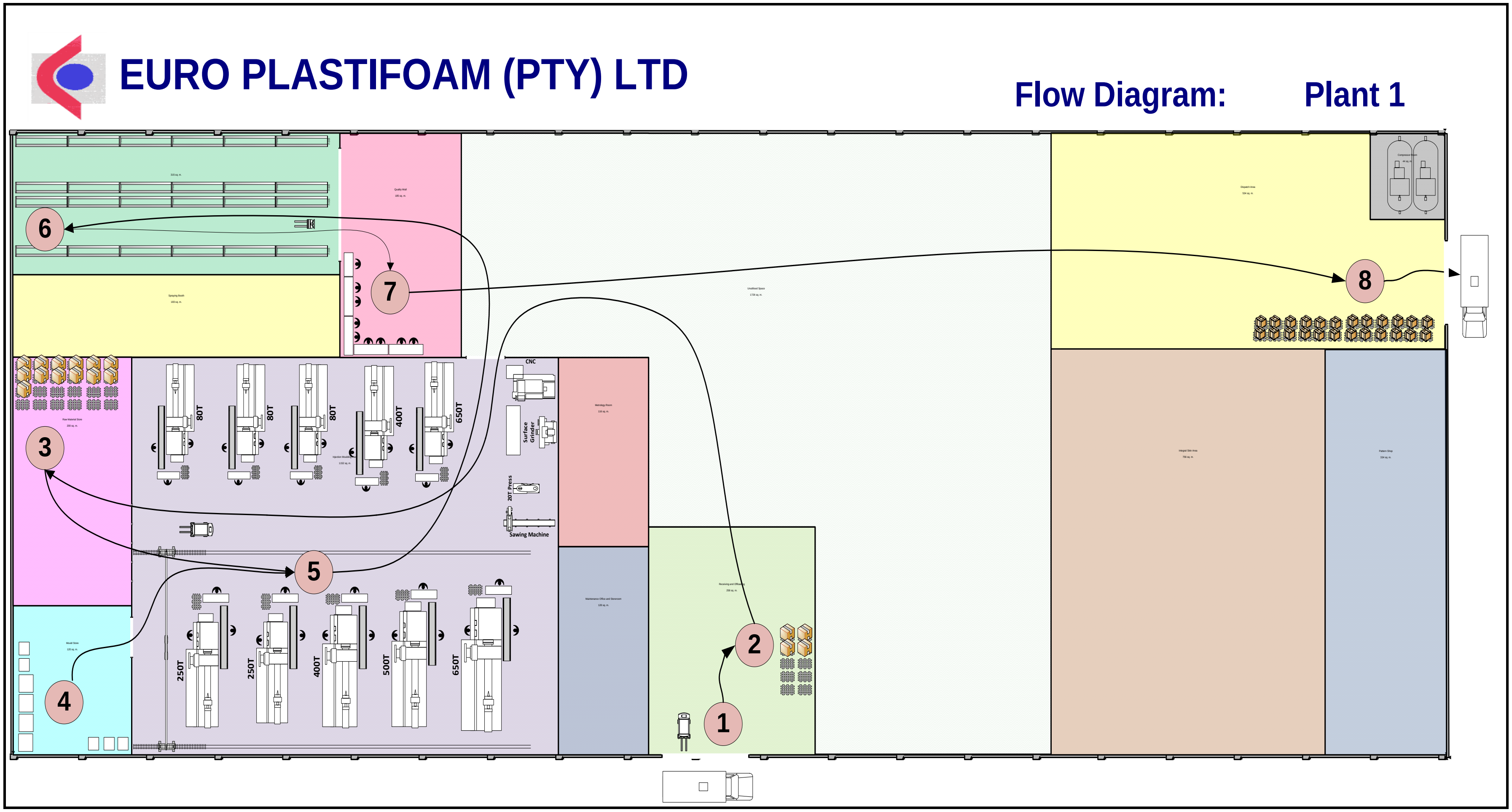


Figure 12: From-To Chart

FROM \ TO	Raw Material Receiving	Temporary Storage of Raw Material	Raw Material Store	Mould Store	Production	Warehousing	Quality Wall	Dispatch	Total Visits	Total Distance
Raw Material Receiving		4 / 13	4 / 78	0 / 82	0 / 61	0 / 66	0 / 49	0 / 63	8	364
Temporary Storage of Raw Material	4 / 13		4 / 65	0 / 69	0 / 48	0 / 53	0 / 36	0 / 50	8	312
Raw Material Store	4 / 78	4 / 65		0 / 4	2 / 22	0 / 80	0 / 63	0 / 125	10	616
Mould Store	0 / 82	0 / 69	0 / 4		1 / 21	0 / 84	0 / 67	0 / 129	1	21
Production	0 / 61	0 / 48	2 / 22	1 / 21		4 / 58	0 / 41	0 / 103	7	297
Warehousing	0 / 66	0 / 53	0 / 80	0 / 84	4 / 58		4 / 17	0 / 113	8	300
Quality Wall	0 / 49	0 / 36	0 / 63	0 / 67	0 / 41	4 / 17		4 / 96	8	452
Dispatch	0 / 63	0 / 50	0 / 125	0 / 129	0 / 103	0 / 113	4 / 96		4	384
Total Visits	8	8	10	1	7	8	8	4	54	
Total Distance	364	312	616	21	297	300	452	384		2746

6.1.4 The injection moulding process

For production to begin the mould is pre-heated in the machine until the appropriate temperature is reached. The correct parameter settings are inserted into the injection moulding machine's computer by the setter, and the first parts can be produced. The parameter settings are not always standardly available, and it takes many experimentation runs before a part is produced that fulfill the quality and dimensional requirements. The data obtained from the injection moulding efficiency study will be analysed in section 6.2 of this report, and the efficiency of the injection moulding process will be covered in depth.

Figure 13: Relationship Diagram

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

Code	Reason
1	Frequency of use high
2	Frequency of use medium
3	Frequency of use low
4	Information flow high
5	Information flow medium
6	Information flow low

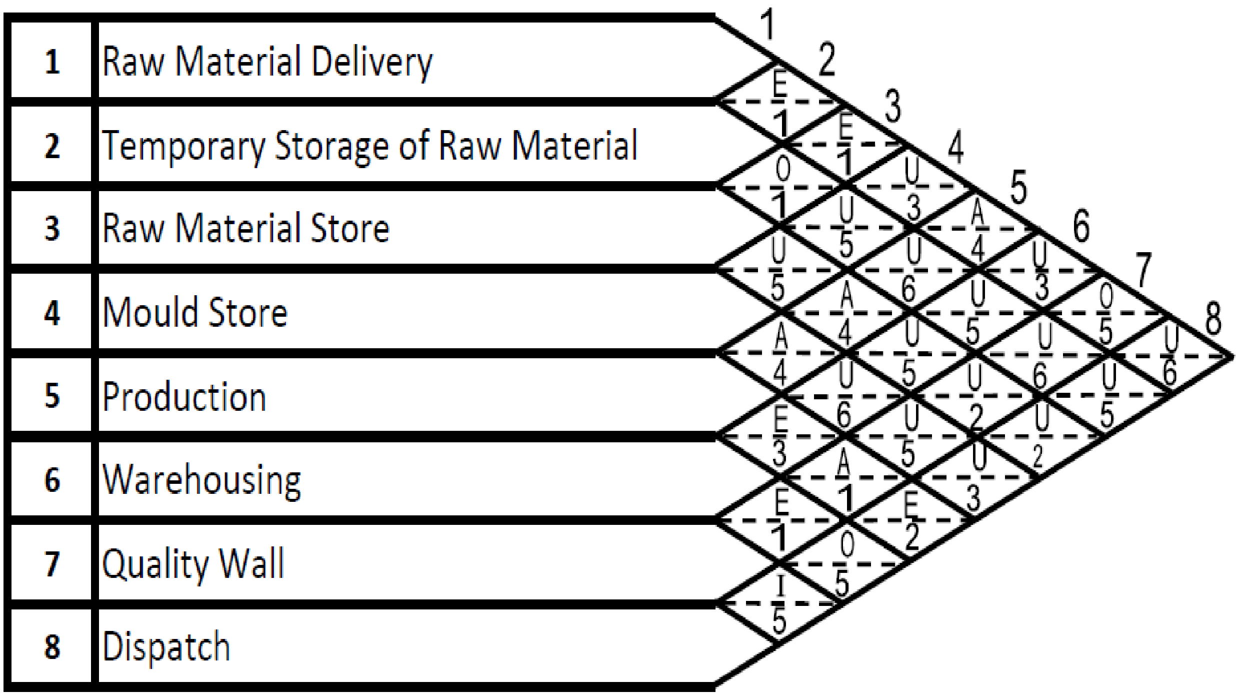
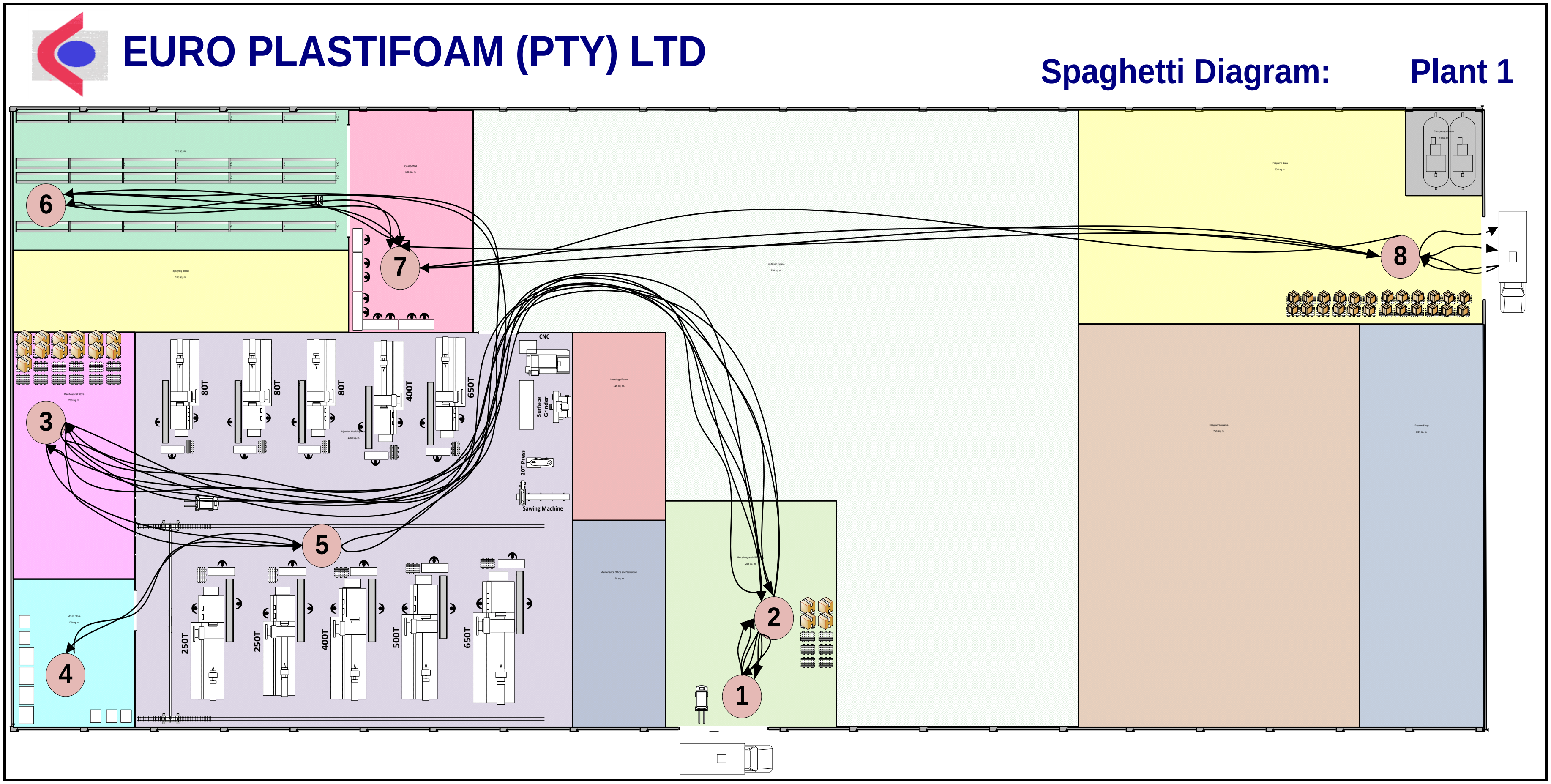


Figure 14: Spaghetti Diagram



6.1.5 Post-production activities performed at the injection moulding machine

As can be seen on the Flow Process Chart, Figure 15 of this report, several processes take place on the line before finished goods are moved to the warehouse.

Firstly, there is an inspector at the injection moulding machine who inspects each part for any visual defects. That person does the necessary trimming and fit the required plastic clips, and after the part has cooled down validates the part's dimensions by fitting it on a checking fixture. There are clear instructions visible for the operators to see for every task that needs to be performed.

A second person on the line inspects the part once again for any visual defects, after which it is wrapped in bubble wrap and packed in the appropriate plastic bins.

6.1.6 Warehousing, Quality Wall and Dispatch

Plastic bins containing the finished goods are collected from the injection moulding machine by an electric pallet stacker, and moved to the warehouse. It is Euro-Plastifoam's policy to keep a five day safety stock of every single part. The reason for this is rigorous penalties by the company's customers for every day the demand is not met.

Before finished goods are moved to the dispatch area, every single part has to go through a final inspection. At the Quality Wall inspectors unpack and unwrap every part and ensure that all quality requirements are met. Each part has to be rewrapped and repacked again, before finished goods are moved to the dispatch area, ready for collection. The dispatch area is located at the north-east corner of the facility, as can be seen in Figure 14 (Indicated by *Number-8)*. There exists a fairly important relationship between the Quality Wall and the dispatch area (as can be seen on the Relationship Diagram in Figure 13), since it's important for all finished goods to be through the Quality Wall and ready for collection before the scheduled collection time. Although it is a large distance that has to be covered by the forklift truck or pallet stacker to move the finished goods from the Quality Wall to the dispatch area, the dispatch area is believed to be located at an optimum location. The reason for this is the presence of a Cul-de-Sac at the end of Phillips Street, right on the outside of the dispatch area. This ensures a quiet street with minimum traffic, and collection trucks can collect the finished goods effectively and efficiently.

Figure 15: Flow Process Chart

Flow Process Chart **Page 1 of 1**

Location **EPF Plant 1**		Summary			
Process **Top Finisher Manual LHD 2x4**		Event	Present	Proposed	Savings
Date **13 / 07 / 2011**		- Operation	**12**		
Operator **Elias**	Analyst **I. Zietsman**	- Transport	**7**		
Circle appropiate Method and Type		- Delay	**2**		
Method: Present Proposed		- Inspection	**4**		
Type: Worker Process Machine		- Storage	**2**		
		Time (min)	**29893**		
		Distance (m)	**329**		
		Cost (R)	N/A		

Legend
Operation
Transportation
Delay
Inspection
Storage

Item	Event Description	Symbol	Time (min)	Distance (m)	Method Recommendation	
1	**Raw Material delivered at Receiving Dock**		9	N/A		
2	**Unloading of Raw Material from delivery truck**		17	13		
3	**Raw Material Inspection**		4	N/A		
4	**Move Raw Material to RM Store**		63	78		
5	**RM is kept in store until required**		21600	N/A		
6	**Issue correct RM (type, colour and quantity)**		8	N/A		
7	**Move RM to Mixing and Blending**		7	22		
8	**Mixing and Blending**		13	N/A		
9	**Mould Change**		96	21		
10	**Material Loading**		18	7		
11	**Enter correct parameter settings into computer**		17	N/A		
12	**Wait for mould to reach correct temperature**		29	N/A		
13	**Injection Moulding - Run required production**		480	N/A		
14	**In-line inpection**		0.25	1		
15	**Trimming & Assembly**		1.5	1		
16	**In-line 2nd inspection**		0.25	1		
17	**Packing**		22	3		
18	**Move parts to Warehouse**		14	58		
19	**Parts kept in warehouse until required**		7200	N/A		
20	**Move parts to Quality Wall**		13	17		
21	**Unpack parts**		11	N/A		
22	**Final Inspection**		43	N/A		
23	**Repack parts**		16	N/A		
24	**Move to Dispatch Area**		9	96		
25	**Wait for Collection Truck**		180	N/A		
26	**Load Finished Goods into collection truck**		16	11		
27	**Issue Delivery Note**		6	N/A		

6.2 Analysis of the injection moulding efficiency data

As developed in Chapter 4 of this report, and discussed in section 5.3, comprehensive data have been collected for a period of two months regarding the efficiency of the injection moulding process itself. Any inefficiencies and areas of waste for every day of production have been identified and captured in a spread sheet. The total downtime for each day is calculated in the spread sheet, based on the three injection moulding machines under investigation. The summarised results from the two months' data can be viewed in Table 7.

Table 6: Summarised results from injection moulding efficiency study

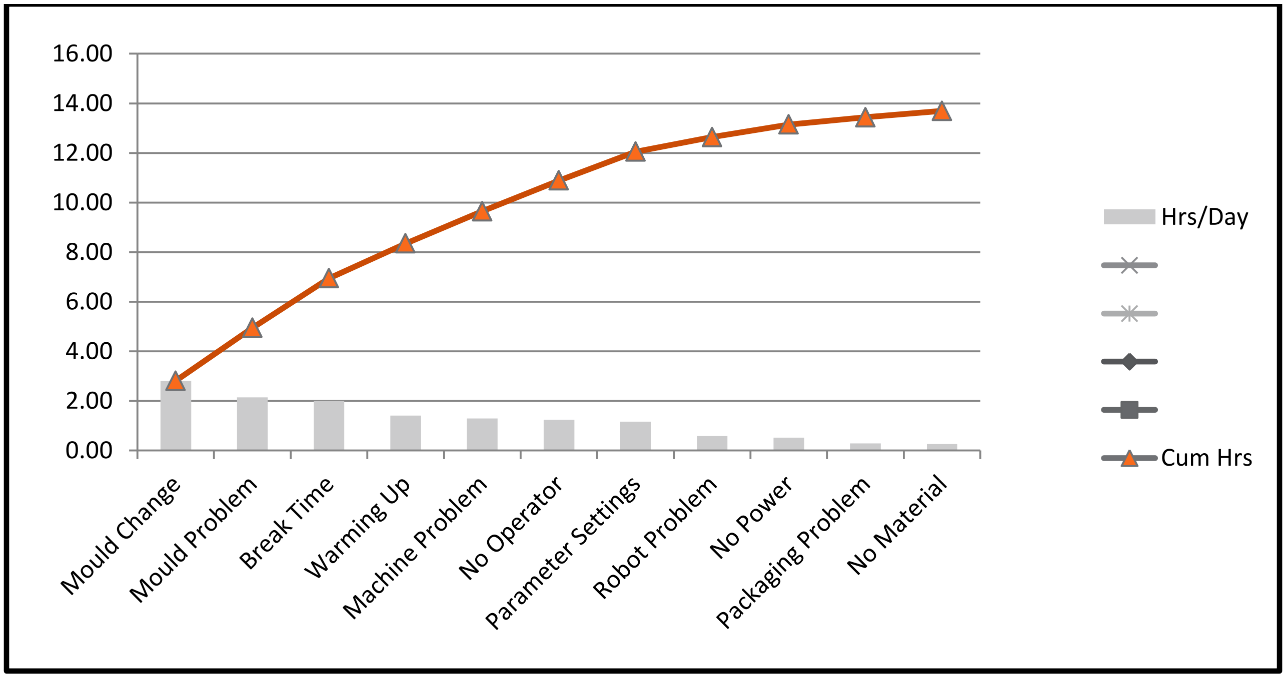
Factor/Cause	**Machine: 650T** (Average Downtime/day)	**Machine: 400T** (Average Downtime/day)	**Machine: 250T** (Average Downtime/day)
Warming Up	1.4	1.43	1.39
Packaging Problem	0.38	0.14	0.34
Machine Problem	1.28	1.46	1.14
Mould Problem	2.55	2.86	1
Robot Problem	0.62	0.15	0.98
Mould Change	2.94	3.04	2.44
Parameter Settings	1.46	1.01	1.03
No Material	0.31	0.26	0.21
No Power	0.41	0.41	0.72
No Operator	1.14	1.33	1.25
Break Time	2	2	2
Total Average Downtime/day	**14.33**	**13.81**	**12.86**
Efficiency	**40.30%**	**42.47%**	**46.42%**

From Table 7 it is clear that a vast amount of resources are wasted daily due to inefficiencies in injection moulding-related processes. On average, each injection moulding machine is only 43% efficient and has a downtime 13 hours. Clearly this is a very big problem and a massive opportunity for improvement.

6.2.1 Pareto Analysis

In order to confirm whether only a small number of factors are responsible for the biggest fraction of waste, Pareto Analysis was performed. Results can be viewed in Figure 16. It is clear that the commonly found *80/20 Principle* is not represented, and therefore meaning that 20% of the factors are not responsible for 80% of the Downtime. It will be advisable however, to prioritse the improvements starting with the problems responsible for the biggest amount of downtime.

Figure 16: Pareto Analysis



6.2.2 Bar Graph and Pie Chart

In order to create a visual representation of the impact and the role each identified problem plays in the overall downtime of every injection moulding machine, the efficiency information are presented on a Bar Graph, which can be viewed in Figure 17, and also on a Pie Chart, which is showed in Figure 18.

Figure 17: Bar Graph

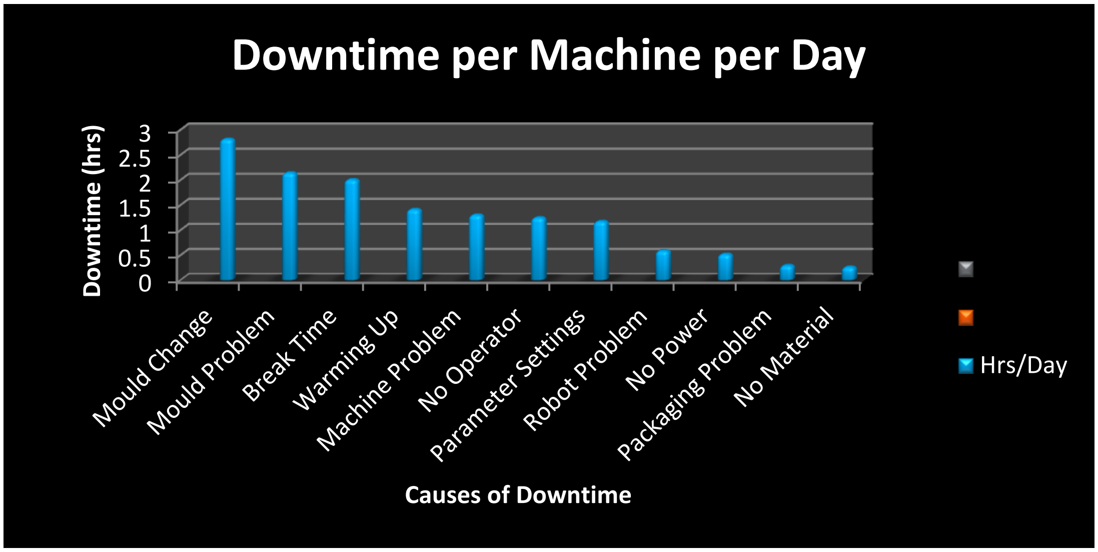
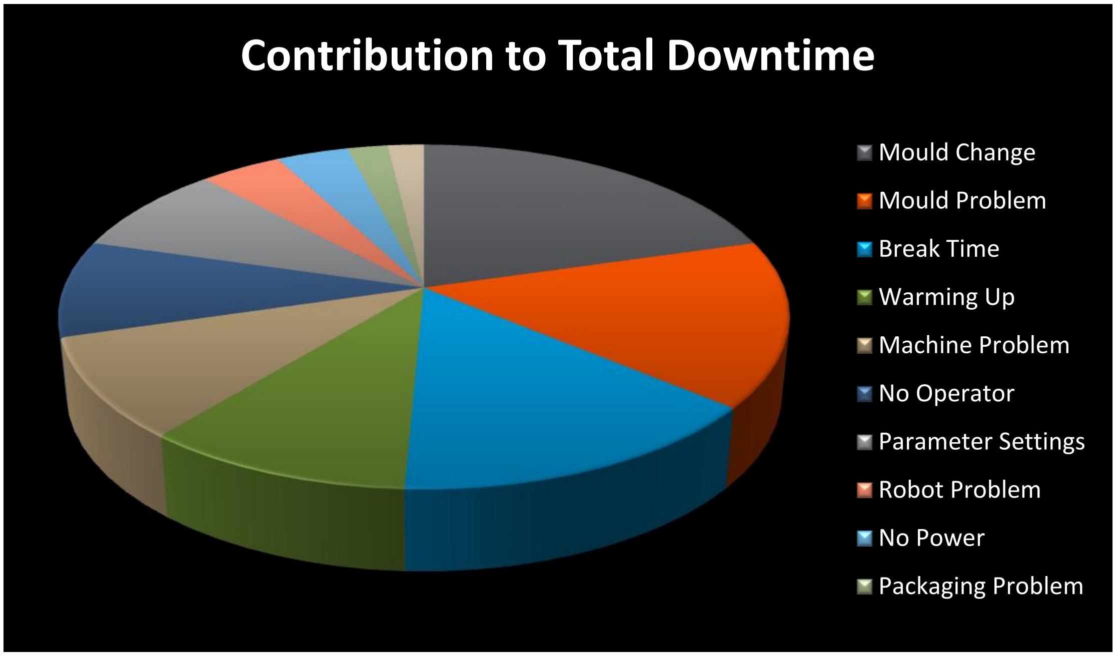


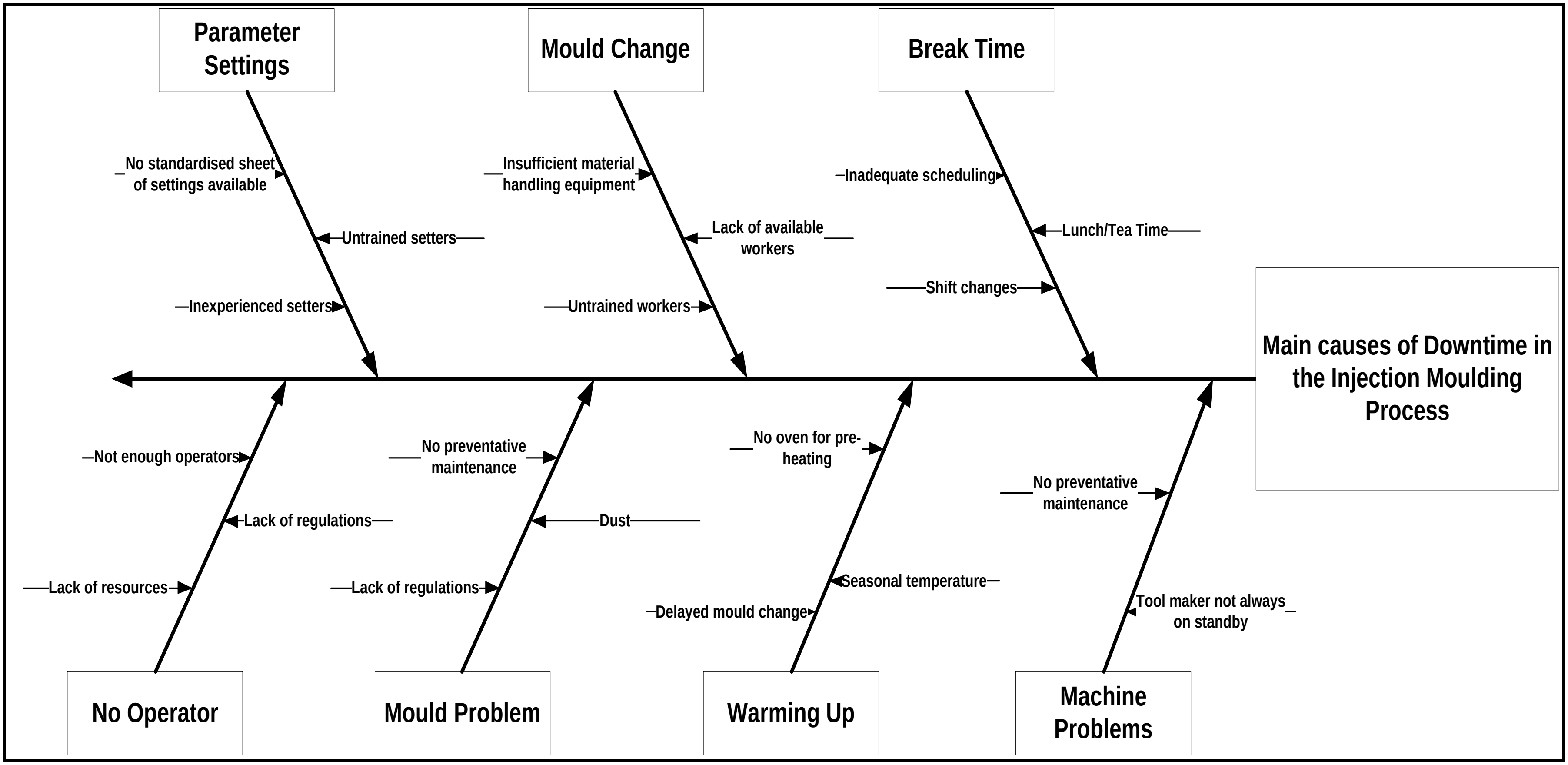
Figure 18: Pie Chart



6.2.3 <u>Fishbone Diagram</u>

Further analysis of the causes behind all the downtime was done by utilizing the fishbone diagram, which can be viewed in Figure 19.

Figure 19: Fishbone Diagram



Chapter 7: Design and Problem Solving

In this chapter the focus will shift to the design of alternative methods or work procedures, and problem solving with the aim of improving the production process flow and eliminating waste.

Possible solutions will be identified for the problems, as discussed in Chapter 6 of this report. This will be followed by the selection of the best and most appropriate solutions, after which the chosen solutions will be implemented and another month's injection moulding efficiency data will be collected. Finally, the solutions will be validated by gathering all future state information and drawing up the future state value stream map. This will be followed by other future state analyses, including a From-To Chart, Flow Diagram, Spaghetti Diagram, and a summary of the results from the newly done injection moulding efficiency study.

7.1 Solution Identification

Various methods have been utilised to aid with the solution identification process. All data have been analysed and problem areas identified in Chapter 6 of this report. The first step in determining possible solutions for the identified problems was various brain-storming sessions held at Euro-Plastifoam involving all key role players. The problems previously identified were clearly explained to everyone, and classic brain-storming sessions followed where possible ideas, solutions and improvements were formulated and noted. Complimentary to the brain-storming sessions, interviews were conducted with various employees involved in the production process, and research was done on the application of various Industrial Engineering methods, tools and techniques with the aim of improving the system.

7.1.1 Ordering of Raw Material

It was suggested that in stead of ordering the whole month's raw material at once, the orders should rather be placed on a weekly basis. In able to make a success of this newly proposed ordering policy, it is critical to have a meeting with the material supplier and negotiate the new request. A commitment can be made with the material supplier that Euro-Plastifoam will switch to this single supplier for all raw material demand, in turn for more frequent, on time deliveries. This ordering policy change will result in raw material inventory reducing by 75%.

7.1.2 Layout improvements

A great improvement to the production process flow of the company, as well as an upgrade to the facilities would be to make a change in the location of the raw material receiving dock. The suggested location is shown by the yellow arrow in Figure 21. The suggested solution is to let raw material delivery trucks deliver raw material directly at the Raw Material Store. Because raw material inventory levels will reduce by 75% if the ordering policy change is made as discussed in subsection 7.1.1, there will be more than sufficient space available in the Raw Material Store for material handling equipment to operate when unloading raw material. To make this proposed improvement a possibility, a change needs to made with regards to the traffic flow within the facilities. It is suggested that another gate is installed at the west side of the facilities facing Doreen Avenue. This gate will only be used as an exit. The proposed change is indicated on the satellite photo in Figure 20. This change will result in a major reduction in traffic-related problems within the facility. Traffic flow will be absolutely fluent and delivery trucks won’t cause any congestion. The gate at Phillips Street will then be used only as an entrance, and the gate at Doreen Avenue as the exit.

Another proposed improvement to the facility layout is to move the warehousing area to the location as indicated by the green block in Figure 21. This will improve process flow and create the possibility of expanding the warehouse if such a need ever arise.

Figure 20: Satellite photo depicting proposed layout improvements

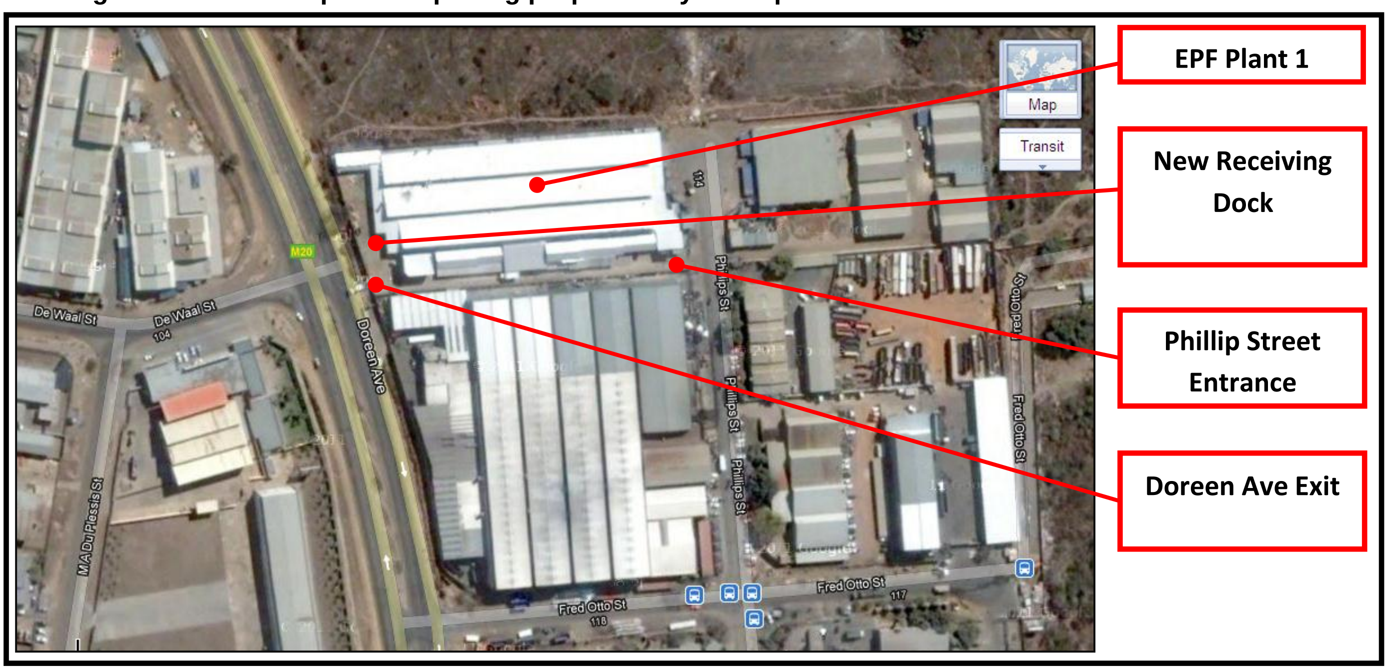
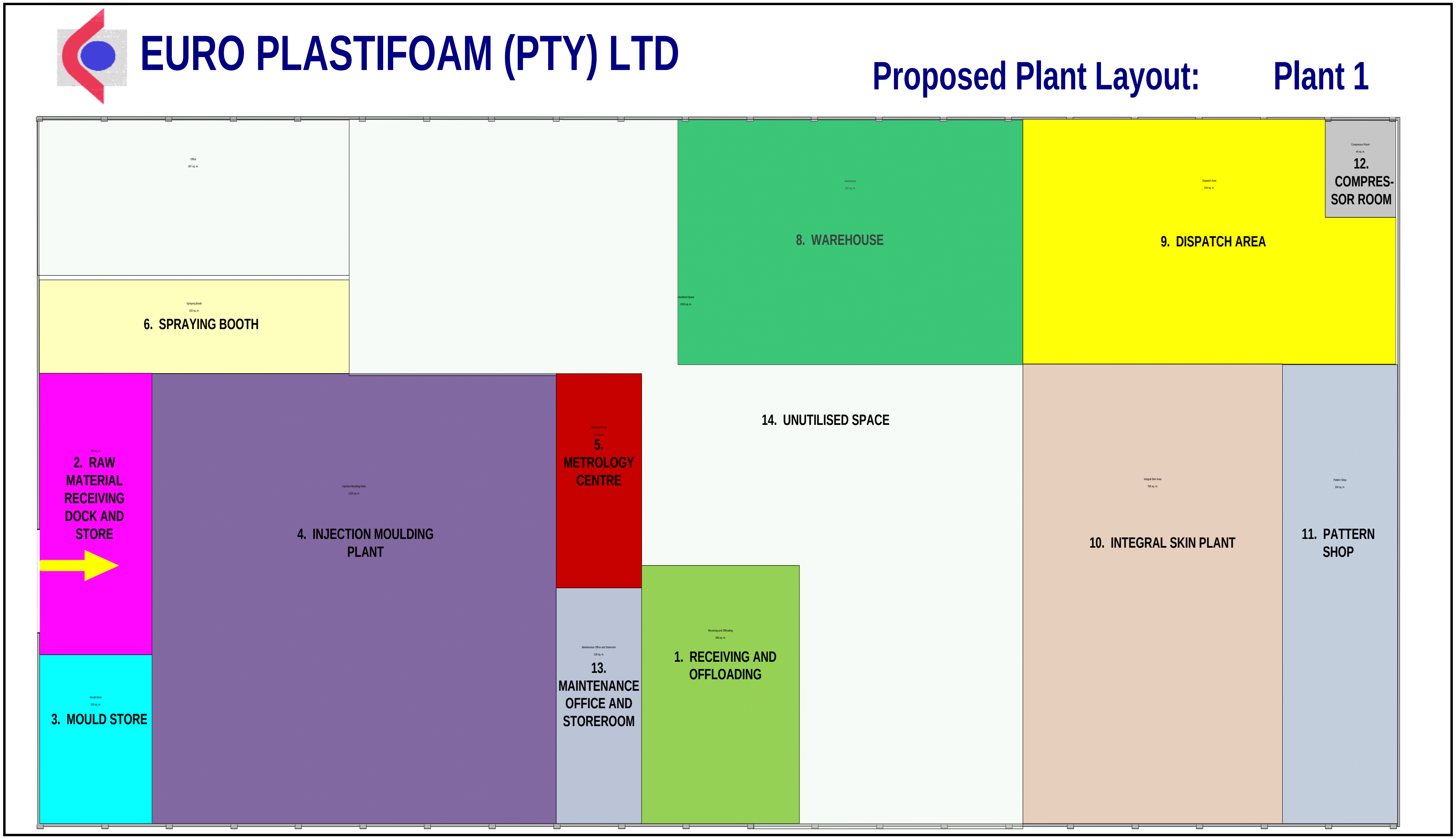


Figure 21: Proposed Plant Layout



7.1.3 Improvement of the process flow

One process that was identified as an area of waste and opportunity for improvement is the Quality Wall. Every single part produced at Euro-Plastifoam must go through this final inspection stage before leaving the facilities. Although the quality standards for parts produced in the automotive industry are rigorous and penalties for supplying parts with defects very high, this final inspection stage is an area of total waste. No value is added to the part, and from a logistical perspective it makes no sense. The reason for this being that every part is already inspected twice, wrapped in bubble wrap and packed in the appropriate packaging unit. As explained in Table 5, at the Quality Wall every part is unpacked and unwrapped, inspected for any defects, rewrapped and repacked, and then sent to the dispatch area.

The proposed solution is remove the Quality Wall from that position in the production process, put one inspector at every injection moulding machine, and therefore creating a mini Quality Wall on the line of production. Every part will still be inspected three times, but now the third and final inspection will take place on the production line before the parts are wrapped in bubble wrap and packed in the bins.

7.1.4 Training and Appointment of new personnel

After thorough data collection and analysis it is found that there exists a definite need for additional personnel to be appointed at Euro-Plastifoam.

a) A second toolmaker needs to be appointed urgently. From the injection moulding efficiency study done and analysed in section 6.2 of this report, it became visible that an average of 2 hours are wasted daily at every injection moulding machine due to mould problems. These problems are mainly due to the fact that there is no toolmaker appointed to work during night shift. Therefore, if any problem occurs with a mould in that time, then production is standing still at that machine until the toolmaker arrives.
b) It is also clear from the injection moulding efficiency study that there is a lack of operators for the injection moulding machines. From the study it was found that over 80 minutes are written off as downtime on a daily basis for every injection moulding machine. Since there are ten injection moulding machines in plant, it sums to a total 12 hours wasted. It is suggested that 3 trained operators be appointed.
c) It was found that on average, 85 minutes are wasted daily at every machine due to machine problems, and 50 minutes due to robot problems. Since there is no employee

working at Euro-Plastifoam trained to attend to electrical and electronical problems like these, when such a problem arises an external technician has to be called out. If Euro-Plastifoam could appoint an Electric or Electronic Engineer, a vast amount of time and money could be saved.

d) It is strongly recommended that the setters currently employed by Euro-Plastifoam are sent on a sufficient training course. In total, 10 hours are wasted daily due to experimentation with parameter settings every time a new mould is loaded into the injection moulding machine for production. Standardised lists of parameter settings for every part to be kept at every injection moulding machine will also make a big difference.

7.1.5 Material Handling Equipment

From the data collected and analysed it is clearly visible that Euro-Plastifoam can gain a lot by investing in a second forklift truck, and a gantry crane over the second half of the injection moulding plant. Both of these items of additional equipment will aid immensely with mould changes, which are the single biggest cause of downtime in the injection moulding process.

7.1.6 Introduction of a Kanban System

It is very strongly recommended that a Kanban System is implemented in the production line. This lean manufacturing tool can reduce production lead time, reduce inventory and save money. For optimal results, five Kanban sets need to be implemented at various points in the production process at Euro-Plastifoam. Each of these sets consists of a Withdrawal Kanban and a Production Kanban. The first place where a Kanban is required is at the Raw Material Store. This will continually ensure that the optimal level of raw material for each part is kept in stock, and also that the correct amount of raw material is issued for each production run. The second place for a Kanban is at the injection moulding process. The third Kanban is required at Trimming & Assembly, the fourth at the Quality Wall, and the last Kanban at the warehouse.

7.1.7 Introduction of SMED (Single Minute Exchange of Dies)

The only reason for the introduction of SMED is to reduce the time it takes to do a mould change. As it can be seen in Figure 17, mould changes are the single biggest cause of downtime in the injection moulding process at Euro-Plastifoam. The following steps need to be followed in order to successfully implement SMED in the production line:

a) The current process needs to be thoroughly observed and analysed. This has already been done, as discussed in Chapter 5 and 6 of this report.
b) Distinguish between the work done while the injection moulding machine is running production (internal processes), and the work done while the machine is idle (external processes).
c) Convert as much external processes possible to internal ones; meaning that all the work possibly required to be done for a mould change needs to be prepared and done before active production on that specific injection moulding machine is finished.
d) Streamline the internal processes.
e) Streamline the external processes that were not possible to convert.

7.1.8 Introduction of 5S House keeping

At the inspection, trimming, and assembly workstations the principles of 5S house keeping can be very beneficial. It is very easy to implement, and can reduce any non-value adding activities at these workstations. The following steps will be followed in order to ensure these principles are implemented correctly:

a) Identify the necessary equipment and articles needed at the respective workstation to effectively perform the required task at hand. Make sure there are no unnecessary objects at the work station.
b) Put all necessary equipment on its exact place at the workstation.
c) Schedule hourly cleaning sessions for the trimmers, assemblers and inspectors. During these very quick cleaning sessions, each person has to quickly tidy up their own workstation.
d) Design clear labels for every piece of necessary equipment which indicates exactly where that piece of equipment needs to be placed when not in use. An example is the trimmer's trimming knives.
e) Together with the person's involved, agree and set the standards for cleanliness and the procedure that will have to be followed to keep to these standards.

7.2 Selection of the best solutions

Consecutive meetings were scheduled with the management of Euro-Plastifoam in order to decide which solutions will be implemented, which will be planned to be implemented at a later stage, and which solutions will be rejected.

The Critical Analysis Technique was used to methodically and logically analyse some of the alternative solutions discussed in Section 7.1 and helped Management to make informed decisions. The application of this technique is showed in Table 8.

It was decided that the following solutions will be implemented immediately, in order to test and validate them:

- Changing the Raw Material ordering policy from one month to one week.
- Delivering Raw Material directly at the raw material store.
- Removing the Quality Wall, and adding a final inspection process to the production line at each injection moulding machine.
- Additional personnel, as recommended in Subsection 7.1.4 will be hired for a period of one month in order to validate the solution.
- Before an investment will be made in another forklift truck, it forklift truck will be hired for a period of one month in order to validate the solution.
- Implementation of a Kanban System.
- Implementation of SMED.
- Implementation of 5S House keeping.

It was decided that the following solutions need further planning and will be implemented at a later stage in time:

- Building a new exit for the facility at Doreen Avenue.
- Installing additional warehousing at the location as specified in Figure 21.
- Setters will be sent for training as soon as possible.
- An investment in a gantry crane to cover the second half of the production plant will be made in CW45.

The following proposed solution was scrapped and will not be implemented:

- The appointment of an Electric or Electronic Engineer.

Table 7: Critical Analysis Technique

PRESENT METHOD		ALTERNATIVES	SELECTED ALTERNATIVE
Purpose – What is planned to be done? *a: Kanban* *b: 5S House keeping*	**Is it necessary? [yes/no]** **If yes – why?** *a: Yes, can reduce inventory and save money.* *b: Yes, can eliminate non-value adding activities*	**What else might be done?** *a: MRP, ERP.* *b: General cleanliness procedures and other lean manufacturing techniques*	**What should be done?** *a: Kanban* *b: 5S House keeping*
Means - How will it be done? *a: By creating a set of cards to represent ever part* *b: By following the steps, as stated in Subsection 7.1.8*	**Why must it be done that way?** *a: It is the way it should be done.* *b: These steps were recommended by relevant research.*	**How else could it be done?** *a: Electronically* *b: By creating your own steps*	**How should it be done?** *a: By creating a set of cards.* *b: By following the predetermined steps.*
Place – Where will it be done? *a: Raw material store, injection moulding, trimming and assembly, Quality Wall and Warehouse.* *b: Trimming, assembly and inspection workstations*	**Why will it be done there?** *a: Most critical aspects of the production process.* *b: It is required.*	**Where else might it be done?** *a: Raw material receiving, dispatch.* *b: Injection moulding*	**Where should it be done?** *a: Raw material store, injection moulding, trimming and assembly, Quality Wall and Warehouse.* *b: Trimming, assembly and inspection workstations*

Sequence – When will it be done? *a: CW31* *b: CW31*	Why will it be done then? *a: Soonest time possible* *b: Soonest time possible*	When else might it be done? *a: Anytime after CW31* *b: Anytime after CW31*	When should it be done? *a: CW31* *b: CW31*
Person – Who will do it? *a: Ignus Zietsman, Manie Neethling* *b: Ignus Zietsman, David Blaai*	**Why will that person do it?** *a: Project Manager and Production Manager* *b: Project Manager and Production Supervisor*	**Who else might do it?** *a: Jacques Wessels* *b: Ockie Engelbrecht*	**Who should do it?** *a: Ignus Zietsman, Manie Neethling* *b: Ockie Engelbrecht*

7.3 Solution Implementation

All solutions were implemented in the production process as specified in Section 7.2.

The solutions identified that will be implemented at a later stage in time still need more planning.

There is one proposed solution that was scrapped and will not be implemented, namely the appointment of an Electric or Electrical Engineer. Alternatively it was decided that Euro-Plastifoam's maintenance manager will be sent on the required training programs in order to gain the necessary knowledge to repair the most common occuring breakdowns on the injection moulding machines, and on the injection moulding machines' robots.

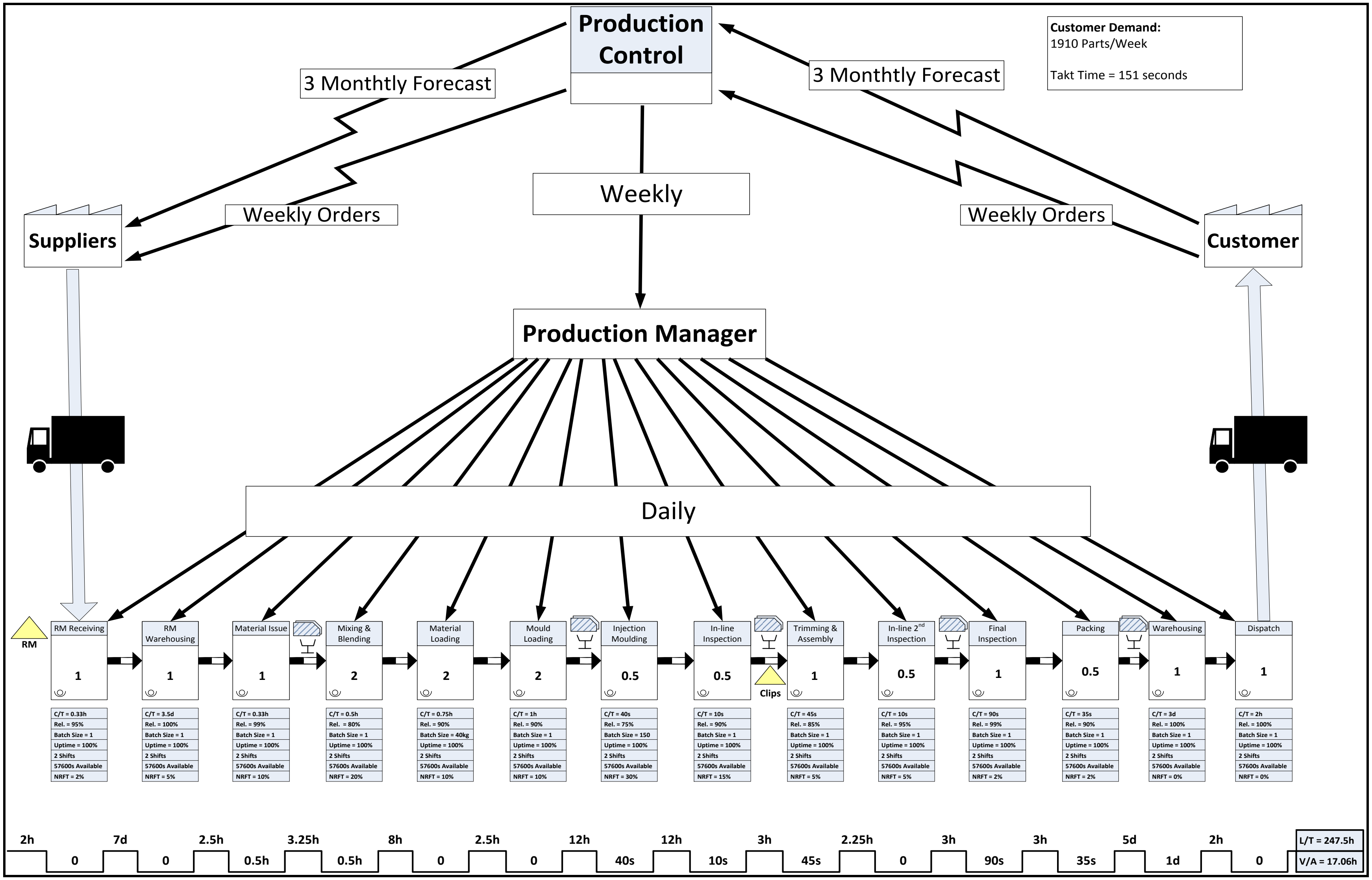
7.4 Solution Validation

After implementation of the chosen solutions, data was again collected and analysed, and all future state information regarding a medium-sized order of Top Finisher Manual LHD 2x4 parts were summarised. This future state information can be observed in Table 9. The future state information is required in order to create the future state Value Stream Map, which is showed in Figure 22.

Table 8: Future State Information

Cell	Cycle Time (C/T)	No. of Operators	Reliability	Not Right First Time (NRFT)	Value Added Time (VA)	Lead Time (L/T)
Raw Material Receiving	0.33h	1	95%	2%	0	2h
Raw Material Warehousing	3.5d	1	100%	5%	0	7d
Material Issue	0.33h	1	99%	10%	0.5h	2.5h
Mixing and Blending	0.5h	2	80%	20%	0.5h	3.25h
Material Loading	0.75h	2	90%	10%	0	8h
Mould Loading	1h	2	90%	10%	0	2.5h
Injection Moulding	40s	0.5	75%	30%	40s	12h
In-line Inspection	10s	0.5	90%	15%	10s	12h
Trimming and Assembly	45s	1	85%	5%	45s	3h
In-line 2nd Inspection	10s	0.5	95%	5%	0	2.25h
Final Inspection	90s	1	99%	2%	90s	3h
Packing	35s	0.5	90%	2%	35s	3h
Warehousing	3d	1	100%	0%	1d	5d
Dispatch	2h	1	100%	0%	0	2h

Figure 22: Future State Value Stream Map



If we compare the future state Value Stream Map with the current state Value Stream Map, we see that as result of the change in the Raw Material ordering policy, the improved plant layout and the additional material handling equipment, it was possible to reduce the production lead time from 699.5 hours to 247.5 hours.

From Figure 23 it is confirmed that the total travelling distance internal to Euro-Plastifoam for the production cycle is 1170m. If compared to the current state From-To Chart, we had a total travelling distance of 2746m. Therefore, the improvements made in the layout of the facility and the final inspection process being combined with the injection moulding process had as result a 57% improvement in the total travelling distance.

Figure 23: Future State From-To Chart

FROM \ TO	Raw Material Receiving	Temporary Storage of Raw Material	Raw Material Store	Mould Store	Production	Warehousing	Quality Wall	Dispatch	Total Visits	Total Distance
Raw Material Receiving		0 / 0	4 / 4	0 / 82	0 / 61	0 / 66	0 / 61	0 / 63	4	16
Temporary Storage of Raw Material	0 / 0		0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0	0
Raw Material Store	4 / 4	0 / 0		0 / 4	2 / 22	0 / 80	0 / 22	0 / 125	6	60
Mould Store	0 / 82	0 / 0	0 / 4		1 / 21	0 / 84	0 / 21	0 / 129	1	21
Production	0 / 61	0 / 0	2 / 22	1 / 21		4 / 58	4 / 0	0 / 103	11	297
Warehousing	0 / 66	0 / 0	0 / 80	0 / 84	4 / 58		4 / 58	4 / 10	12	504
Quality Wall	0 / 61	0 / 0	0 / 22	0 / 21	4 / 0	4 / 58		0 / 103	8	232
Dispatch	0 / 63	0 / 0	0 / 125	0 / 129	0 / 103	4 / 10	0 / 103		4	40
Total Visits	4	0	6	1	11	12	8	4	46	
Total Distance	16	0	60	21	297	504	232	40		1170

The improved production process flow and newly implemented layout of Euro-Plastifoam can be observed in both the future state Flow Diagram in Figure 24, and the future state Spaghetti Diagram in Figure 25.

As part of the Solution Validation, another injection moulding efficiency study was performed. The study was performed exactly the same way as described in Section 5.3, only this time data was recorded for one month (August 2011). Also, this time all improvements were made and the solutions were in place, like the implementation of the Kanban System, SMED, 5S House keeping, and all other improvements as discussed in Section 7.2. The summarised results can be viewed in Table 10, and the results speak for themselves.

Through the implementation of the discussed methods, tools and techniques it was possible to improve the injection moulding process' efficiency from 43% to 77% efficient.

Figure 24: Future State Flow Diagram

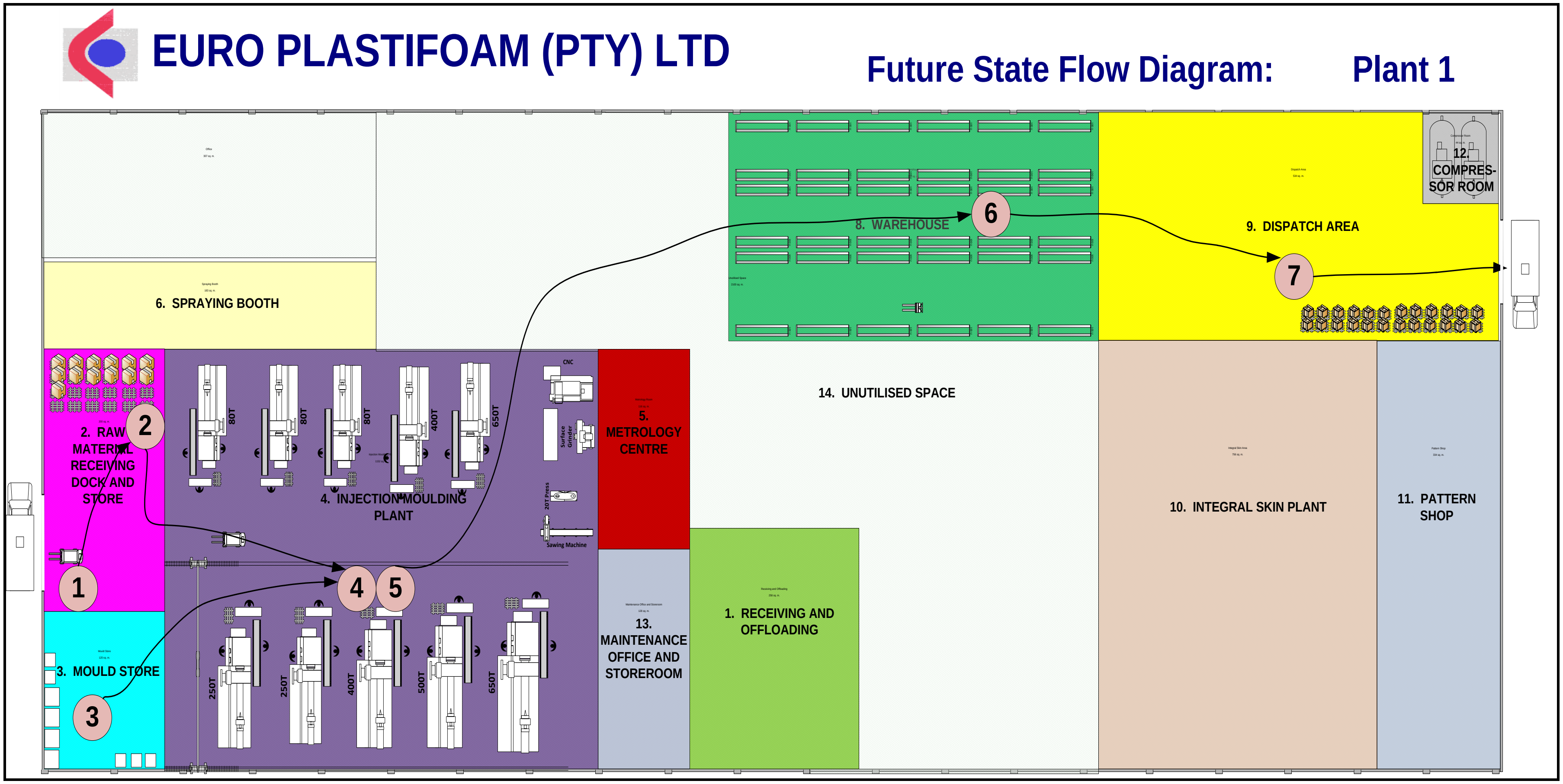


Figure 25: Future State Spaghetti Diagram

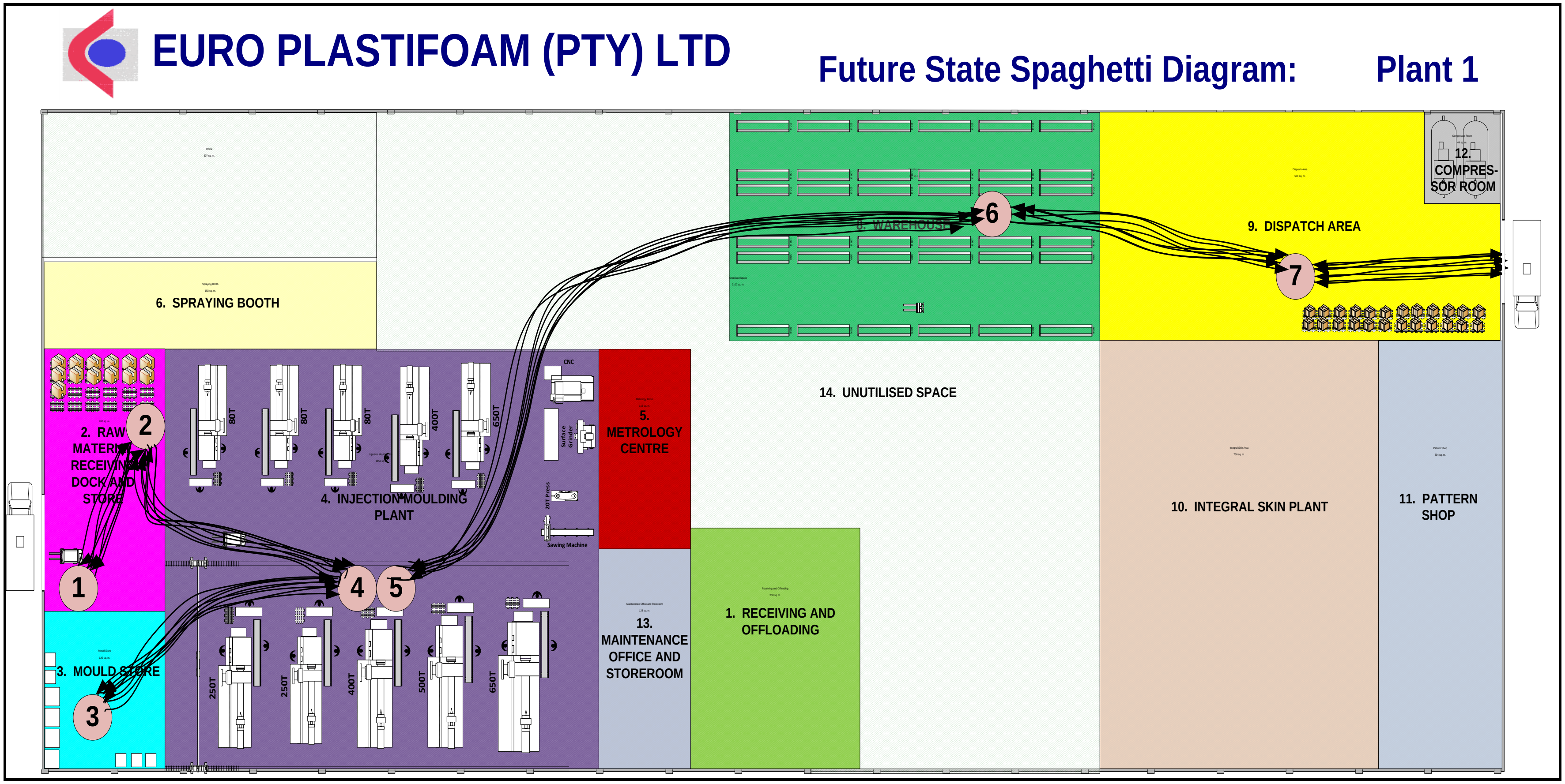


Table 9: Summarised results from injection moulding efficiency study

Factor/Cause	**Machine: 650T** (Average Downtime/day)	**Machine: 400T** (Average Downtime/day)	**Machine: 250T** (Average Downtime/day)
Warming Up	1.21	1.19	1.23
Packaging Problem	0.16	0.41	0.21
Machine Problem	1.16	1.51	1.08
Mould Problem	1.31	0.66	1.15
Robot Problem	0.65	0.25	0.14
Mould Change	0.45	1.09	1.23
Parameter Settings	0.21	0.15	0.16
No Material	0.05	0.03	0.09
No Power	0.00	0.00	0.16
No Operator	0.03	0.11	0.02
Break Time	0	0	0
Total Average Downtime/day	**5.23**	**5.4**	**5.47**
Efficiency	**78.21%**	**77.5%**	**77.20%**

Chapter 8: Recommendations

The following improvements were made to the injection moulding production process, and validated in Section 7.4:

- Changing the Raw Material ordering policy from one month to one week.
- Delivering Raw Material directly at the raw material store.
- Removing the Quality Wall, and adding a final inspection process to the production line at each injection moulding machine.
- Additional personnel, as recommended in Subsection 7.1.4 will be hired for a period of one month in order to validate the solution.
- Before an investment will be made in another forklift truck, it forklift truck will be hired for a period of one month in order to validate the solution.
- Implementation of a Kanban System.
- Implementation of SMED.
- Implementation of 5S House keeping.

Based on the results obtained in Section 7.4, it is strongly recommended for these improvements to be implemented on a permanent basis.

It was decided that the following solutions need further planning and will be implemented at a later stage in time:

- Building a new exit for the facility at Doreen Avenue.
- Installing additional warehousing at the location as specified in Figure 21.
- Setters will be sent for training as soon as possible.
- An investment in a gantry crane to cover the second half of the production plant will be made in CW45.

It is believed that these changes will even further improve the production process flow at Euro-Plastifoam, therefore they also come highly recommended.

Conclusion

With a methodical and logical approach the production process flow in the injection moulding plant at Euro-Plastifoam was prominently improved.

Comprehensive data collection was performed, the data analysed, and the current state of the process captured by making use of Value Stream Mapping. Areas of waste and opportunities for improvement were identified and possible solutions carefully formulated. Several solutions were selected and implemented, including the implementation of a Kanban system, SMED and 5S House keeping. In order to validate the chosen solutions, it was implemented for a period of one month during which new data was collected and results recorded. It was now possible to draw up the future state Value Stream Map of the production process.

Results and improvements made include:

- a reduction in production lead time from 699.5 hours to 247.5 hours
- a 57% reduction in the total production process travelling distance
- an improvement to the injection moulding process' efficiency from 43% to 77%.

The improvement and optimisation of a production process is not a task performed only once, but a never-ending cycle. It was proven with this project that by applying Industrial Engineering methods, tools and techniques it is possible to make significant improvements to any production process.

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Appendices

Appendix A: Process Efficiency Data capturing spread sheet

Figure 27: Injection Moulding Efficiency Measurement spread sheet – 1 April 2011

EURO-PLASTIFOAM Injection Moulding Efficiency Measurement

Machine 1	JOB NR	Planned time to produce	Real Time Work	Warming up	Packaging Problem	Machine Problem	Mould Problem	Robot Problem	Mould Change	Parameter Settings	No Material	No Power	No Operator	Break Time	Other	Target	Production Actual	Good	Bad
							60 Seconds		60 Shots/hour										
Mould T6 7600	16.00 66.67%	8.00 33.33%	3.00 37.50%	0.50 6.25%	0.00 0.00%	0.00 0.00%	2.00 25.00%	0.00 0.00%	1.00 12.50%	0.50 6.25%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.00 12.50%	0.00 0.00%	480	131 27.29%	104 21.67% 79.39%	27 20.61% 25.96%
							40 Seconds		90 Shots/hour										
Mould T6 7623	7.00 43.75%	9.00 56.25%	1.75 19.44%	0.25 2.78%	0.00 0.00%	0.00 0.00%	5.00 55.56%	0.00 0.00%	1.50 16.67%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.50 5.56%	0.00 0.00%	810	244 30.12%	230 28.40% 94.26%	14 0.00% 6.09%
							45 Seconds		80 Shots/hour										
Mould T6 7614	0.00 0.00%	7.00 100.00%	1.50 21.43%	0.50 7.14%	0.00 0.00%	3.50 50.00%	0.00 0.00%	0.00 0.00%	1.00 14.29%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.50 7.14%	0.00 0.00%	560	164 29.29%	146 26.07% 89.02%	18 10.98% 12.33%
Total	0.00 0.00%	24.00 100.00%	6.25 26.04%	1.25 5.21%	0.00 0.00%	3.5 14.58%	7.00 29.17%	0 0.00%	3.5 14.58%	0.5 2.08%	0.00 0.00%	0.00 0.00%	0.00 0.00%	2.00 8.33%	0.00 0.00%	1850	539 29.14%	480 25.95% 89.05%	59 10.95% 12.29%
				Downtime			17.75 hrs	73.96%											
Machine 2	JOB NR	Planned time to produce	Real Time Work	Warming up	Packaging Problem	Machine Problem	Mould Problem	Robot Problem	Mould Change	Parameter Settings	No Material	No Power	No Operator	Break Time	Other	Target	Production Actual	Good	Bad
							40 Seconds		90 Shots/hour										
Mould B90 6721	21.00 87.50%	3.00 12.50%	0.50 16.67%	0.50 16.67%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.00 33.33%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.00 33.33%	0.00 0.00%	270	100 37.04%	96 35.56% 96.00%	4 4.00% 4.17%
							40 Seconds		90 Shots/hour										
Mould B90 6718	13.00 61.90%	8.00 38.10%	2.75 34.38%	0.75 9.38%	0.00 0.00%	0.00 0.00%	2.50 31.25%	0.00 0.00%	1.00 12.50%	0.50 6.25%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.50 6.25%	0.00 0.00%	720	279 38.75%	235 32.64% 84.23%	44 0.00% 18.72%
							35 Seconds		102.85714 Shots/hour										
Mould X11J 8921	0.00 0.00%	13.00 100.00%	7.50 57.69%	0.50 3.85%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.50 11.54%	1.00 7.69%	0.00 0.00%	0.00 0.00%	2.00 15.38%	0.50 3.85%	0.00 0.00%	1337.1	637 47.64%	596 44.57% 93.56%	41 6.44% 6.88%
Total	0.00 0.00%	24.00 100.00%	10.75 44.79%	1.75 7.29%	0.00 0.00%	0 0.00%	2.50 10.42%	0 0.00%	3.5 14.58%	1.5 6.25%	0.00 0.00%	0.00 0.00%	2.00 8.33%	2.00 8.33%	0.00 0.00%	2327	1016 43.66%	927 39.83% 91.24%	89 8.76% 9.60%
				Downtime			13.25 hrs	55.21%											
Machine 3	JOB NR	Planned time to produce	Real Time Work	Warming up	Packaging Problem	Machine Problem	Mould Problem	Robot Problem	Mould Change	Parameter Settings	No Material	No Power	No Operator	Break Time	Other	Target	Production Actual	Good	Bad
							50 Seconds		72 Shots/hour										
Mould T6 7604	19.00 79.17%	5.00 20.83%	1.25 25.00%	0.50 10.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.00 20.00%	0.25 5.00%	1.00 20.00%	0.00 0.00%	0.00 0.00%	1.00 20.00%	0.00 0.00%	360	90 25.00%	71 19.72% 78.89%	19 21.11% 26.76%
							40 Seconds		90 Shots/hour										
Mould T6 7605	16.00 84.21%	3.00 15.79%	0.25 8.33%	0.50 16.67%	0.00 0.00%	0.00 0.00%	1.00 33.33%	0.00 0.00%	0.75 25.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.50 16.67%	0.00 0.00%	270	43 15.93%	38 14.07% 88.37%	5 0.00% 13.16%
							40 Seconds		90 Shots/hour										
Mould T6 7616	10.00 62.50%	6.00 37.50%	2.00 33.33%	0.25 4.17%	0.00 0.00%	0.00 0.00%	0.00 0.00%	0.00 0.00%	1.00 16.67%	0.75 12.50%	0.00 0.00%	1.50 25.00%	0.00 0.00%	0.50 8.33%	0.00 0.00%	540	165 30.56%	150 27.78% 90.91%	15 9.09% 10.00%
Total	10.00 41.67%	14.00 58.33%	3.50 25.00%	1.25 8.93%	0.00 0.00%	0 0.00%	1.00 7.14%	0 0.00%	2.75 19.64%	1 7.14%	1.00 7.14%	1.50 10.71%	0.00 0.00%	2.00 14.29%	0.00 0.00%	1170	298 25.47%	259 22.14% 86.91%	39 13.09% 15.06%
				Downtime			10.50 hrs	75.00%											
Total	10.00 13.89%	62.00 86.11%	6.83 11.02%	4.25 6.85%	0.00 0.00%	3.50 5.65%	10.50 16.94%	0.00 0.00%	9.75 15.73%	3.00 4.84%	1.00 1.61%	1.50 2.42%	2.00 3.23%	6.00 9.68%	0.00 0.00%	5347	1853 34.65%	1666 31.16% 89.91%	187 10.09% 11.22%
				Total downtime			41.50 hrs	66.94%											