

The improvement of the current Primacord® plant at
Sasol Dyno Nobel Pty (Ltd)

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Executive summary

Sasol and Dyno Nobel formed a joint venture (50% Sasol; 50% Dyno Nobel) which is now a leading supplier of industrial explosives and blasting services to various industries in South Africa and some of the neighboring countries.

Sasol Dyno Nobel Pty (Ltd) imports technology from Dyno Nobel in the USA. The products are assembled and manufactured at the Ekandustria facility in Mpumalanga, South Africa. The joint venture manufactures and markets non-electric explosive accessories, including Primacord® detonating cords.

The Primacord® plant is currently operating at sub-par levels and this problem needs to be addressed. Recommendations and changes will be made to the current process and the efficiencies will be improved by de-bottlenecking the current process and applying lean manufacturing principles where applicable.

A literature review was done on various methods, tools and theories to generate ideas on improving the manufacturing process.

A conceptual design was created to get a depiction of what needs to be used in solving the problem and making the project feasible.

Bottlenecks were identified and recommendations were made to improve throughput and decrease inventory build up.

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Introduction and background

Sasol Dyno Nobel Pty (Ltd) is situated in the Ekandustria industrial area near Bronkhorstspuit. The company is the leading manufacturer of explosive accessories in Africa. This joint venture is shared by Sasol (50%) and Dyno Nobel (50%) a world leader in shock tube initiation technology. The venture manufactures and markets non-electric explosive accessories used in mining, quarrying, seismic and construction industries.

The Ekandustria site has manufacturing and assembly facilities for products like the Primadet® range of shock tube assemblies, Trojan® cast boosters and Primacord® detonating cords.

For my project I will be specifically focusing on the Primacord® manufacturing facility. Primacord® is Sasol Dyno Nobel's range of detonation cord. This is a thin flexible cord with an explosive core used as a fuse for various detonations. The cord explodes (rather than burns) at a very reliable rate of between 7000 and 8000 m/s, which allow users to control detonations. The core is made up of pentaerythritol tetranitrate (PETN or pentrite) powder.

The Primacord® plant manufactures a range of detonation cord.

The product range consists of Detacord, E-cord, Zap-cord, SB-cord, Plofadder, each differing in explosive core charge measured in grams PETN per meter (g/m).

The Primacord® operation consists of six process steps in the assembly of the cord - each section of the operation being conducted in a separate building. The reason for the “silo assembly” in different buildings is the explosive limit per building determined by the explosives act. The limit/building is measured in kilogram explosives. The different buildings are labeled and numbered from building 1 to building 6 as indicated below:

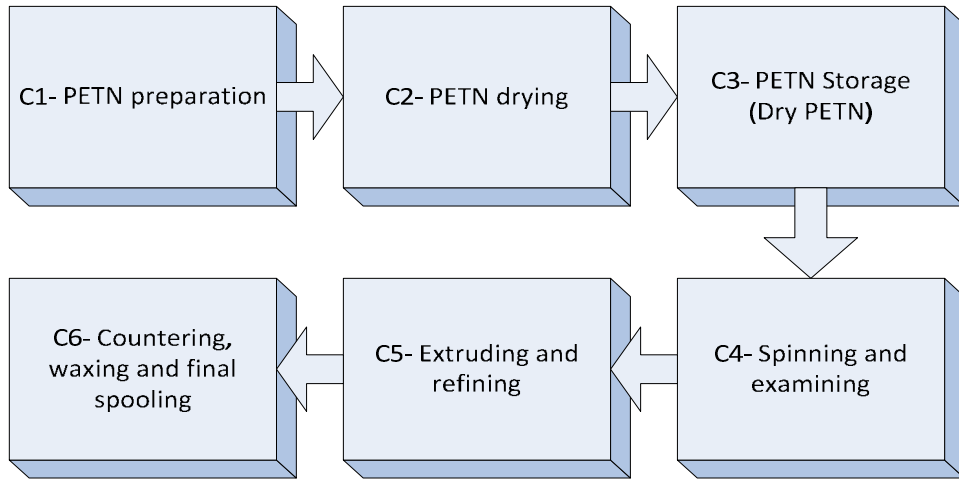


Figure 1 Process flow diagram



Figure 2 Primacord® detonating cord

Project aim

The aim of the project is to determine the current process capability, de-bottleneck and streamline the current Primacord® plant.

The deliverables in achieving the project objectives are the following:

- Do a process capability study using “Time study” data collected, Theory of constraints and Value stream mapping
- Simulating the as-is process using a simulation model
- Improve efficiencies by de-bottlenecking and streamlining the as-is process applying lean manufacturing principles.

Scope

The scope of this project is limited to the Primacord® detonating cord facility at Sasol Dyno Nobel Pty (LTd)

In-depth research will be done on all the possible methodologies to be applied through the course of the project. This will include theory on Time and Capability studies, Theory of Constraints, Value Stream mapping, Simulation modeling, Process optimization and Lean manufacturing.

Comprehensive time study data collection and using the Theory of constraints will provide the information needed to determine the current production capacity of the plant.

The information will be used to develop an as-is value stream map that will be simulated in Arena.

Recommendations and changes will be made to “lean out” the current process and further improve the efficiencies by de-bottlenecking the current process and applying lean manufacturing principles where applicable.

Deliverables

As-is value stream map of the process

Simulation model of the current process

Recommendations on possible process improvements to improve efficiencies

Future state map of the process

Project Plan

Tasks and Activities

Tasks	Activities
1. Research all possible methodologies to be used in project	<ul style="list-style-type: none">• Literature study
2. Capability report	<ul style="list-style-type: none">• Data collection• Document current report• Capability study
3. Value stream map (VSM) of “as is” process	<ul style="list-style-type: none">• Draw up current state map
4. Simulation model	<ul style="list-style-type: none">• Build simulation model on Arena using “as is” VSM
5. Optimization	<ul style="list-style-type: none">• De-bottlenecking of process
6. Proposed future model	<ul style="list-style-type: none">• Draw up future state VSM• Modify simulation to proposed future model
7. Recommendations	

Literature Review

Introduction

Lean manufacturing, Value stream mapping, Capability studies, Simulation modeling and Theory of constraints were the main topics researched for this literature review. These methods, when applied correctly, can aid the process manager in solving problems and improving processes. Through finding the right combination of tools and methods, the process at Sasol Dyno Nobel Pty (Ltd) could be vastly improved.

Lean Manufacturing

Introduction

Shortages of material and resources lead to the growth of “lean” manufacturing processes by the Japanese after World War II. The current lean manufacturing processes were devised by Kiichiro Toyoda, the president of the Toyota motor company at the time. Along with other leading industrial managers (Shigeo Shingo, and Taiichi Ohno), Toyoda created the “Toyota Production system” or “Lean Manufacturing”. (Abdulmalek & Rajgopal, 2007)

The fundamental principle of lean manufacturing is getting a process to produce exactly what the next process requires at the precise time it is required. Smoothing of linked processes result in decreased lead times, high quality and low costs. (Rother & Shook, 1999)

Various problems in different business sectors can be overcome by applying the 5 principles of the lean theory (Womack & Jones, 1996)

- (1) Define value from the perspective of the customer,
- (2) Identify the value streams,
- (3) Flow,
- (4) Pull,
- (5) Strive to perfection.

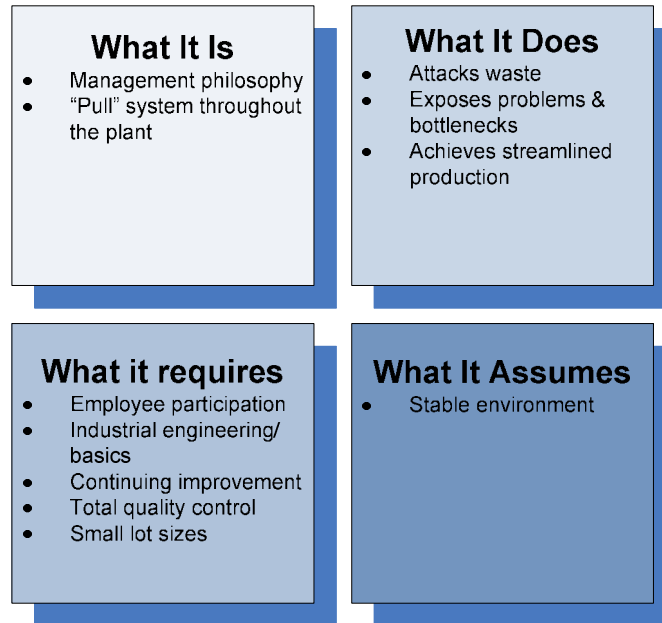


Figure 3 Features of Lean Production (Chase et al., 2006)

Even though a great number of tools and methods of lean manufacturing exists, there aren't many implementation methods. In recent times, *value stream mapping (VSM)* has become the preferred and most successful way to implement lean manufacturing (Lian & Van Landeghem, 2002).

Value stream mapping (VSM)

Rother and Shook (1999) define a value stream as "...all actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product."

Value stream mapping means taking the big picture (not just the independent processes) and putting it on a single page. It is concerned with both information and material flow, creating a visual depiction of a product's path in a system (Rother & Shook, 1999).

This system is based on *muda* (waste) elimination within a production system.

There are seven commonly accepted wastes in the Toyota production system (Hines & Rich, 1997)

- (1) Overproduction;
- (2) Waiting;
- (3) Transport;
- (4) Inappropriate processing;
- (5) Unnecessary inventory;
- (6) Unnecessary motion;
- (7) Defects.

The 4 basic steps of VSM (Rother & Shook, 1999)

- Selection of a product or product family
- Drawing up the current-state value stream map (CVSM)
- Drawing up the future-state value stream map (FVSM)
- Developing of a work plan to change the CVSM to the FVSM

Why VSM?

Advantages:

Muda identification – Business and manufacturing waste occurring in the system can be spotted.

Baseline for improvements – Improvements can start from the current value stream map and be continuously implemented.

Construction of a desired future system – The future value stream maps acts as a goal to work and strive towards.

Some drawbacks of VSM according to (Lian & Van Landeghem, 2002):

- Because VSM is a “paper and pencil” based method it restricts the number of versions and hinders the level of detail that can be achieved.
- Companies produce low volume, high variety, products which lead to complication through the sheer number of value maps.
- There is a possibility of the value stream map ending up as a pretty picture because people aren’t always able to see how it fits into practice.









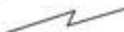




<i>Icon</i>	<i>Icon Name</i>	<i>Description</i>	<i>Icon</i>	<i>Icon Name</i>	<i>Description</i>
	Process box	Describes an activity in the value stream. Includes a title and description of the process, as well as data, like process time, setup time, and so on.		Finished goods movement	Indicates when materials in a finished state are moved along the value stream. This can be a supplier moving its product to a company or a company moving its product to its customer.
	Outside source	Indicates and identifies both customers and suppliers.		Material push	Indicates material being pushed through the process. The push is usually a production plan or schedule.
	Truck	Indicates an outside delivery — either to a customer or from a supplier.		Supermarket	Indicates in-process inventory stored in a controlled environment called a supermarket.
	Information	Describes information transmitted along the value stream.		Material pull	Indicates material movement via a pull signal (kanban).
	Electronic information transmission	Indicates that the information is transmitted electronically.		Operator	Indicates that one or more operators are present at a process step.
	Manual information transmission	Indicates that the information is transmitted manually.		<i>Kaizen</i> burst	Indicates the need for and description of a <i>Kaizen</i> activity within the value stream.
	Inventory	Identifies stored inventory — either raw materials, in process, or finished goods.			

Figure 4 Basic VSM icons (Hines & Rich, 1997)

Capability studies

Chase et al. (1996) defines process capability as “What your process *can* deliver”.

Through data collection, the monitoring of the capability of a system is known as the process capability study. Data needs to be collected from a stable process. Process capability indices are then used to evaluate the data. From this, improvements and alterations can be done. Process capability studies should be conducted following four steps (Deleryd, 1999) (also shown in fig.5).

Step 1: Identify important characteristics, plan the study

Monitoring every single feature of a product is impractical. Before one takes the study, answer simple questions like: “What is to be measured and how?”, “What gauges are to be used and how should they be calibrated?”

Step 2: Establish statistical control, gather data

Processes can't have a rational capability if it doesn't show a reasonable extent of stability. This means a process needs to be statistically in control, for the capability study on an unstable process will be of no use. Statistical process control can be seen by generating control charts. After statistical control has been achieved, data is collected and used in the study.

Step 3: Assess the capability of the process

Drawing a histogram from the control charts generated in step 2, is the simplest way to evaluate the capability of a process. The specification limits in relationship with the histogram will show the capability of a statistically in-control process.

Process capability indices will numerically quantify the capability. These indices are dimensionless functions created to convey simple values of the performance of the process.

Step 4: Initiate improvement efforts

The potential improvement areas recognized must be put into action to accomplish a more capable process. This however will not solve the problem, but will provide suggestions on how to reach the improvement objectives.

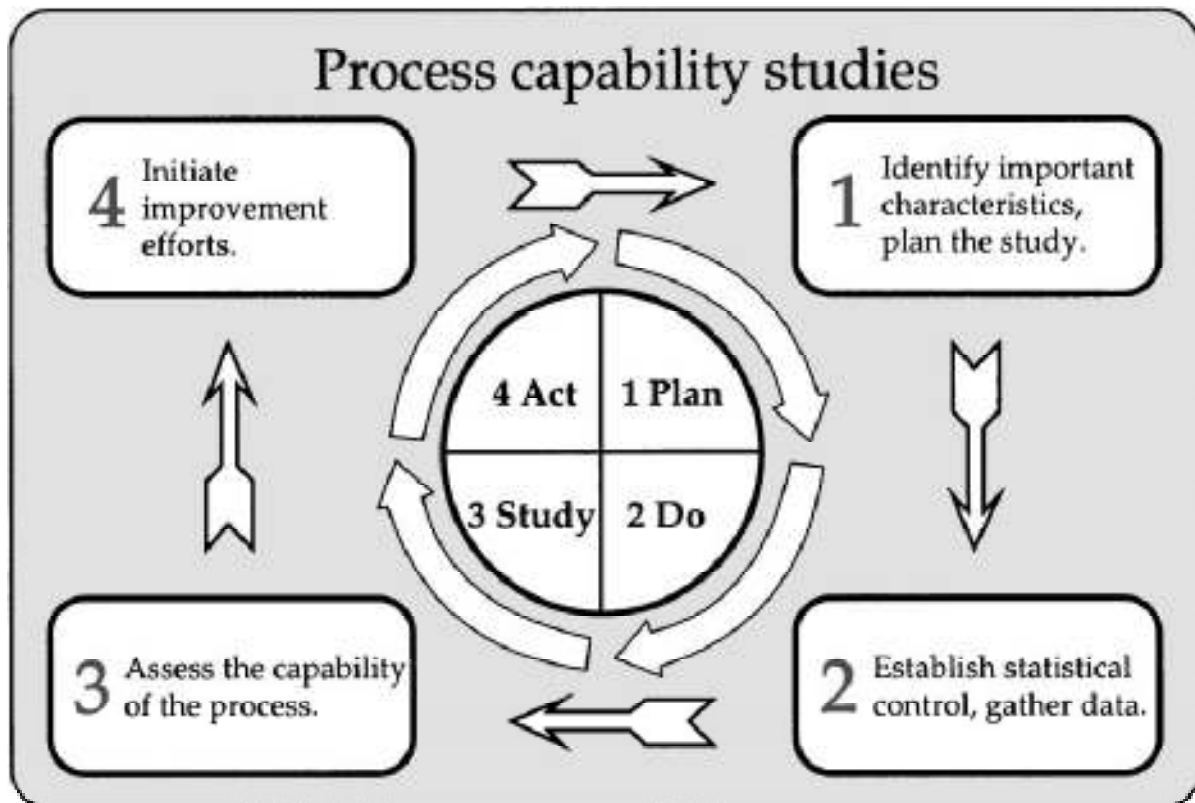


Figure 5 the basic steps of process capability studies, (Deleryd, 1999)

Simulation Modeling

Introduction

Businesses use simulation as a standard tool. In manufacturing simulation is used for production schedules, inventory leveling, maintenance, capacity planning and requirements of resources. In service, waiting lines and schedule processes are analyzed with simulation. "Often, when a mathematical technique fails, we turn to simulation" (Chase et al., 2006).

Application of Simulation in Support of VSM

People are afraid of change. Traditional manufacturing systems and managers are unwilling to commit to new and strange approaches such as lean manufacturing, for it is often hard to predict the exact results achieved by applying these methods. Decisions on implementing now rely on the “belief” in lean manufacturing, results of previous lean applications, and a general rule on the expected results. This is not persuasive enough for managers to adopt these lean principles. Simulation modeling aids in the fulfillment of this gap by making lean manufacturing and VSM more “visible” and thus viable. It quantifies the physical gains in the premature stages of planning and implementation. It handles uncertainty and creates active views for different future value stream maps. Through all of this managers can compare the performance of the current system in relation to the improved future system (Abdulmalek & Rajgopal, 2007).

Some of the advantages and disadvantages (Chase et al., 2006)

Advantages

- A simulated model leads to a better understanding of the actual process
- Simulation time constrict actual time
- It doesn't hinder with the ongoing activities of the actual system
- Commercially available
- “What-if” questions can be answered through simulation

Disadvantages

- There is never a guarantee that simulation will result in the correct, desired answers
- It is never 100% dependable
- Complex simulations are expensive and time consuming
- It is less accurate than mathematical methods
- It lacks standardization

Theory of constraints (TOC)

In the book “Introduction to the Theory of Constraints” (McMullen, 1998) the question arises “Where did TOC come from?”

These are the answers:

- Dr. Eli M. Goldratt was the originator
- TOC existed all along, waiting to be discovered
- *Parts* of TOC were discovered by *lots* of people
- Many people worked on developing TOC
- Graduate students helped Dr Goldratt invent TOC

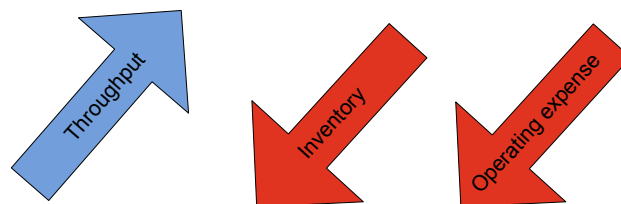
Dr. Eli Goldratt developed the “theory of constraints” as a problem solving approach after sensing that manufacturers were doing poor job scheduling, resource control and inventory control (Chase et al., 2006).

Goldratt had a very simple, straightforward view of the objective of a firm. “The goal of a firm is to make money.”

Two sets of measurements are used in evaluating a company’s performance (Chase et al., 2006).

Financial measurements: Net profit, Return on investment and Cash flow.

Operational measurements: Throughput, Inventory and Operating expenses.



The operational goal of a firm is to increase throughput while reducing inventory and operating expenses

Figure 6 Operational goal (Chase et al.,2006)

After the overall objective of the organization has been determined we take the following steps for on-going improvement:

Five Focusing Steps in the Process of On-Going Improvement (Davies et al., 2005)

Step 1: IDENTIFY the system constraint(s)

Step 2: Decide how to EXPLOIT the constraint

Step 3: SUBORDINATE other activities to decisions made in Step 2

Step 4: ELEVATE the constraint(s)

Step 5: If anything has changed . . . GO BACK to Step 1.

The 5 Steps executed in this framework enables a company to create a stable and dependable value delivery system. From here its decision makers can swiftly react to any opportunity that presents itself. The *TOC Thinking Processes* permits it to create strategies to grab hold of those opportunities so that value would be generated for all stakeholders and strategic advantages will occur. "An organization using TOC is only limited by how big it dares to think. **Imagine!**" (Avraham, 2009)

Bottlenecks

Chase et al (2006) defines a bottleneck as "a resource whose capacity is less than the demand placed upon it." It is a throughput limiting constraint in a process and occurs where the flow in a process thins to a leaner than average stream. A bottleneck can be a specialized tool, scarce labor or a machine. Bottlenecks can be overcome by using Drum-buffer-rope-scheduling. (Chase et al., 2006)

Conclusion of Literature Review

Textbooks and theories always differ from reality. One can't think that following a set of rules or using methods step by step you will end up with a successful implementation of process improvement. It is however necessary to follow these guidelines whilst applying knowledge and common sense to find a desired outcome to a specific problem. These methods have been tried and tested and will certainly help along the way and in the end it is about finding the right combination of solutions for each different problem.

Conceptual Design Development

The right combination of the philosophies, tools, theories and methods described in the literature review will lead to a successful improvement of the Primacord® manufacturing process. The goal is to use all available resources to change the current state of the process into a revised and improved future state.

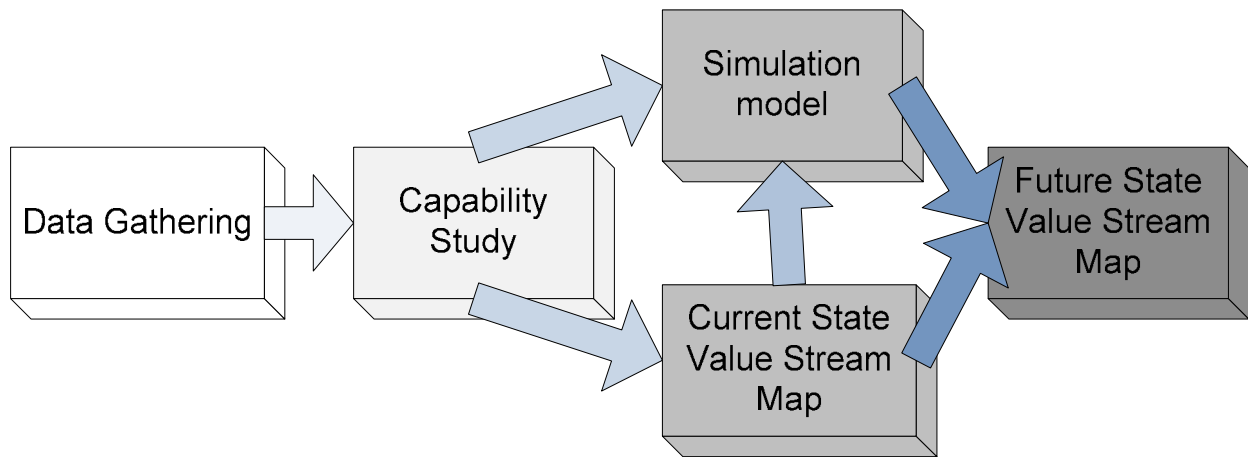


Figure 7 Concept Design

A capability study will be done on a statistically in-control process, to assess the current state of the process. This will then be drawn up on a current state value stream map. A simulation model of the process will be built in Arena to determine bottlenecks and to answer 'what if' questions. Goldratt's theory of constraints and lean manufacturing principles will guide decision making in creating a future state. Waste will be identified and eliminated to draw up a future state value stream map.

With the future state in mind, improvements to the process can be implemented to obtain a smooth, lean and profitable process.

After all, *"The goal of a firm is to make money."*

Current state analysis

Background

Data and ideas were generated by spending a great amount of time at the plant itself. By speaking to the operators, who know every step of the process in detail, I could get a better feel for the system.

In depth time studies were done to get activity times for each of the value adding processes. Changeovers and breakdowns were taken into account in all the lead times. Figure 8 is a representation of the core processes of the plant and indicates both the setup and run times for each activity.

Manufacturing Process and Process Flow

The process starts at PETN preparation (C1) where moist PETN is put into a centrifuge to get rid of the excess water. (PETN is transported in a moist condition to make it more inert.) From here the PETN is dried using 2 convection ovens (C2). The dried PETN powder is then stored in a magazine (C3) until it is needed.

The PETN then moves to C4, Spinning and Examining. The powder is poured into a core which is then covered in yarn to form the inner part of the cord. For the first time in the process the cord is coiled on a spool. Each spool carries around 2000m of cord. The spool is then moved to examination where the cord is put through an automated machine which detects gaps in the core where the powder is absent. When a quality failure occurs, the cord is cut and an operator repairs it by tying a special knot.

The next steps are Extruding and Refining (C5). The cord is put through a machine that adds a layer of polypropylene to make it durable. From here it runs through a refining machine that crushes the core to make the powder finer.

The final steps are Countering, Waxing and Final Spooling (C6). Countering adds another, thicker layer of yarn spun around the cord. This is for strength and identification purposes. Waxing covers the cord in a final top layer of colored wax for durability and identification. The cord is then coiled onto a large Ferris wheel for the wax to dry and for operator inspection. Finally the cord is spun on to smaller coils (of about 250m). These are then wrapped and boxed ready to go to the customer.

Scope

The focus of the project will not cover the PETN preparation processes as this is a continuous process that is always ahead of the demand. Dried PETN powder is always available to go to the first process of spinning (C4)

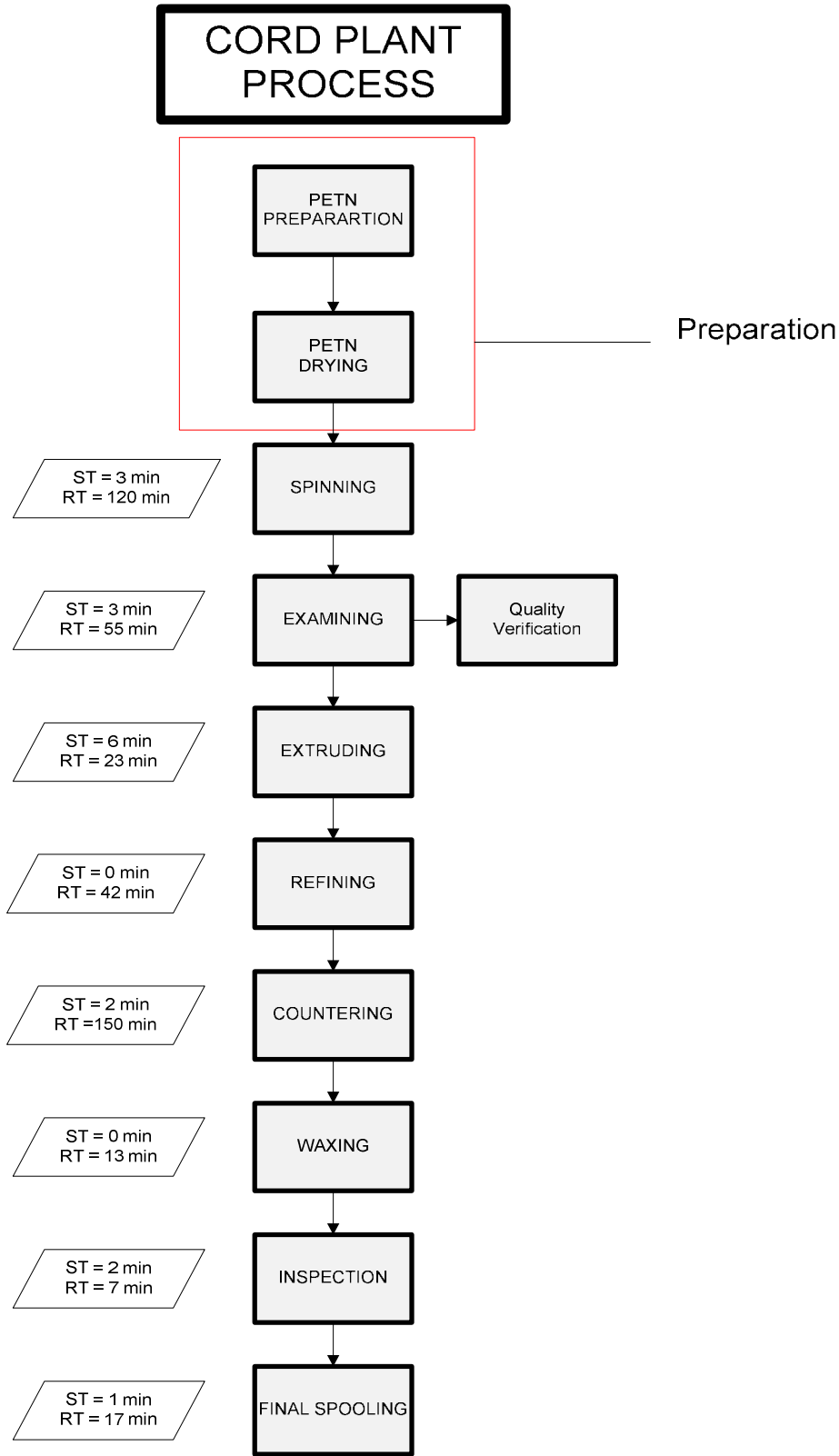


Figure 8 Process flow

Current state

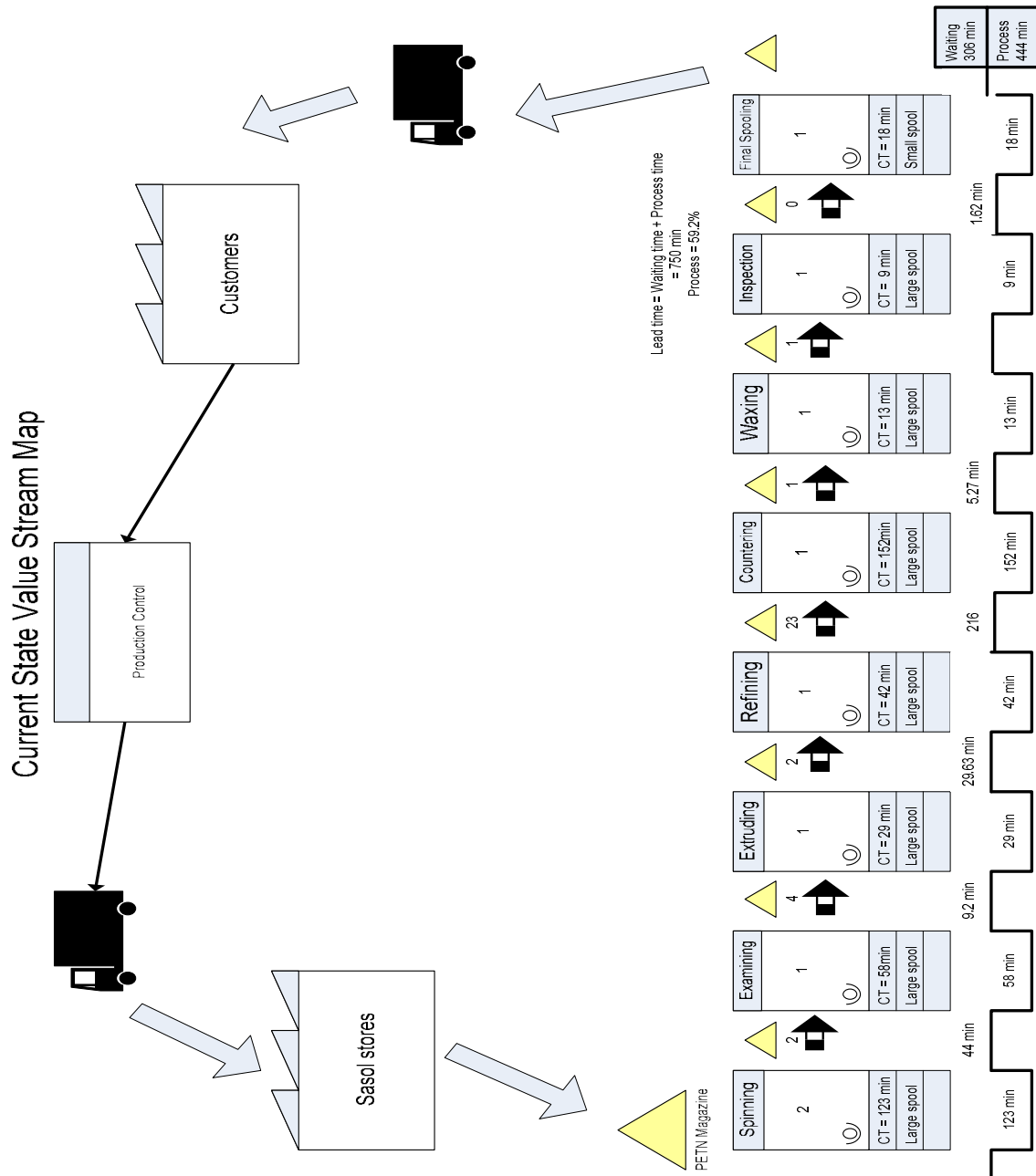


Figure 9 Current State VSM

The current state is drawn up on a Value Stream Map. The map shows measures such as number of workers, the wait, process and cycle times and the level of inventory. The long waiting time (306 minutes) is due to the inventory build-up and queues especially at the countering process due to a large bottleneck. Countering thus forms the biggest constraint and needs to be optimized. A bottleneck should be eliminated as far as possible. If the constraint has been optimized to the greatest extent and it still creates a problem, it should be managed by making sure the constraint is always in process and that the bottleneck is always fed and never stands still.

Simulation approach

The simulation model will determine the bottlenecks in the system and will give an indication of what will happen when conditions change. The flow of the system will also be looked at.

The model will be run for 40 hours. (8 hours per day run on a 5 day week). Create models will regulate the demand. A new part (1 large spool will be counted as 1 entity/batch/part.) For a start, a new part will be created every 120 min. This will be altered to see the change in the process

Utilization (resource measure), queuing (process measure) and number of finished spools (system measure) will be looked at.

A counter will be inserted to count every finished spool. Bottlenecks will be determined by analyzing the waiting times of entities in queues. The utilization of the resources will be monitored especially when the conditions change.

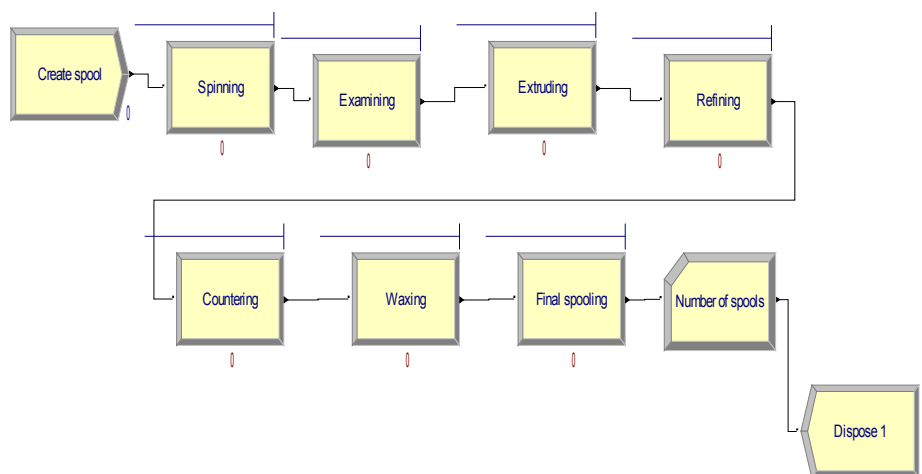


Figure 10 BASIC model

Simulation Analysis

The first simulation was run for 40 hours. The IAT times of the raw material (empty spools) were altered to get different results and to get a feel for how drastic the changes will influence the system.

Five different inter arrival times were checked at the beginning. Spools arrive 10 at a time, as there are 10 spinners at the first process.

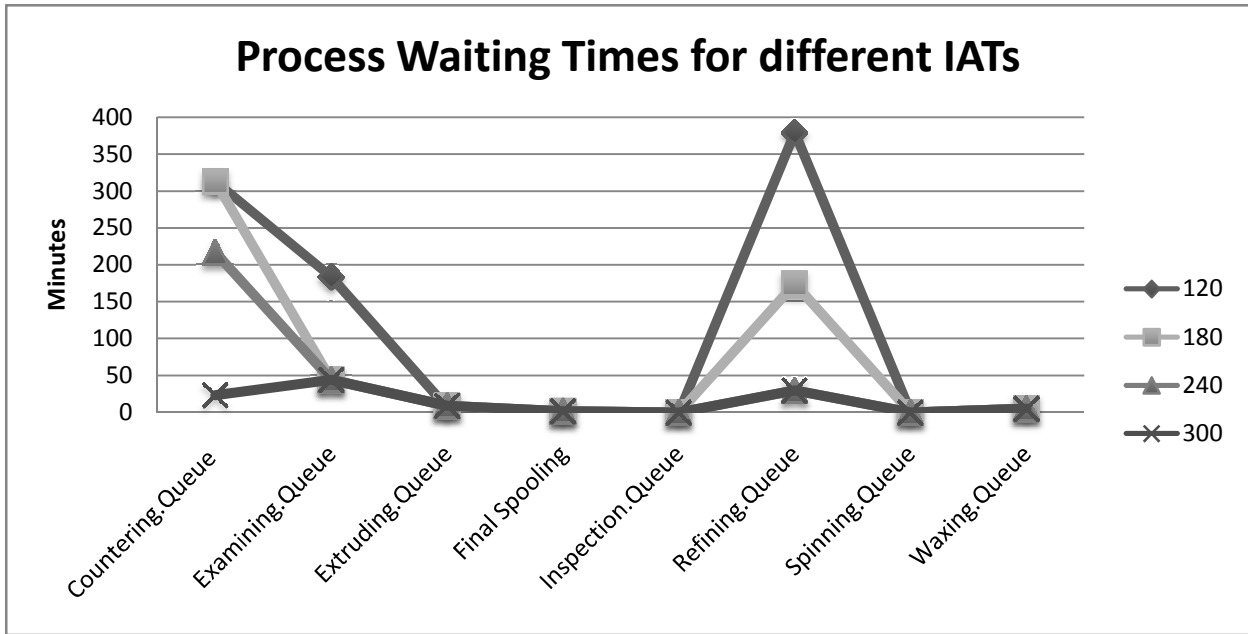


Figure 11 Process Waiting Times

To reduce the queues, the optimal IAT for the empty spools should be 300 minutes, which means a new batch should start on the spinning process every 300 minutes. The difference in queue lengths can clearly be seen at the different IAT's. Also note the long queues at refining, examining and especially at countering. Countering is the most time consuming process and there is only 5 countering machines. The long queue at refining is due to the backlog of spools as the refining process precedes the countering process.

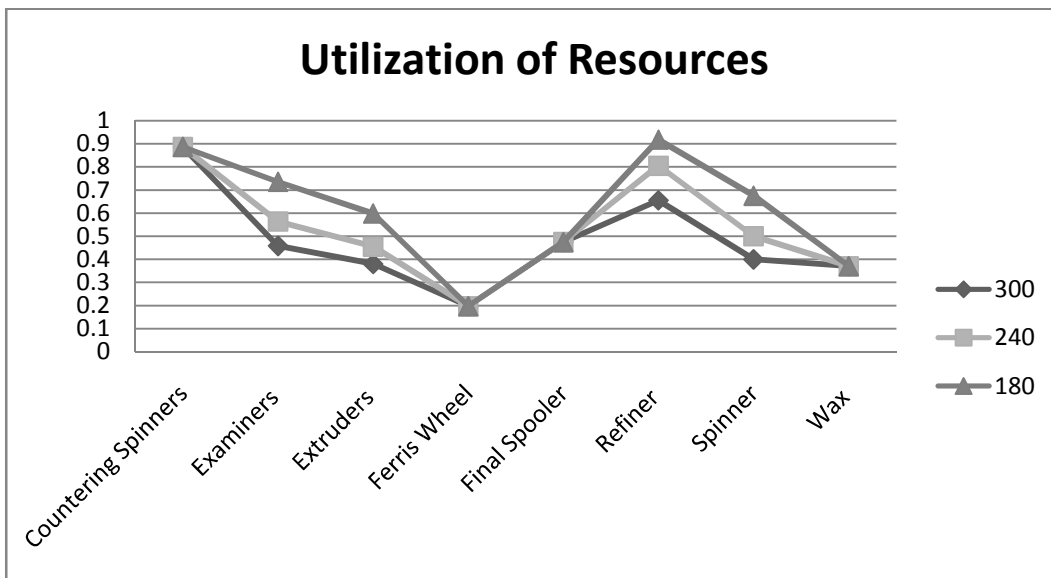


Figure 12 Resource Utilization

It can clearly be seen that some machines are over- and under-utilized. This will create a problem when demand is increased. This also means that the process isn't running at optimal conditions.

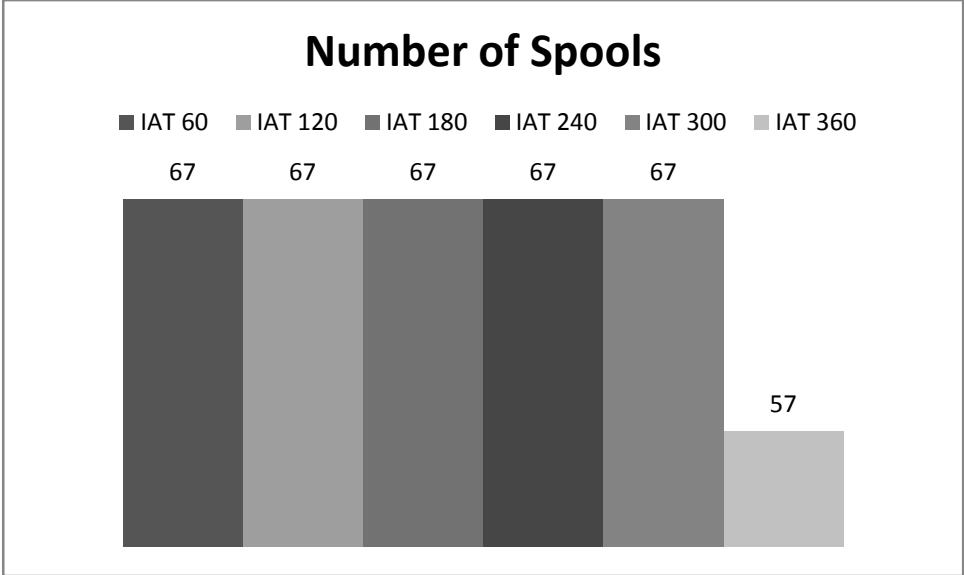


Figure 13 Spools out

The above figure shows that the difference in inter arrival time does not affect the numbers of spools produced, which means a bottleneck occurs. The bottleneck occurs at Countering.

Current state Conclusion

The current output can be achieved by only utilizing 5 of the spinning machines, due to the constraint at countering.

The improvement of the current state depends solely on the changes that can be made to the countering process. As it is an automatic process, not much can be done about the cycle time of the process. Inventory ahead of the process should be minimized, and the effects of increasing the number of countering machines should be investigated.

Future State

If the number of counteracting machines is to be increased (currently there are 5 machines), it would lead to the following:

5 counteracting spinners = 67 spools out.

6 counteracting machines = 80 spools out.

7 counteracting machines = 93 spools out.

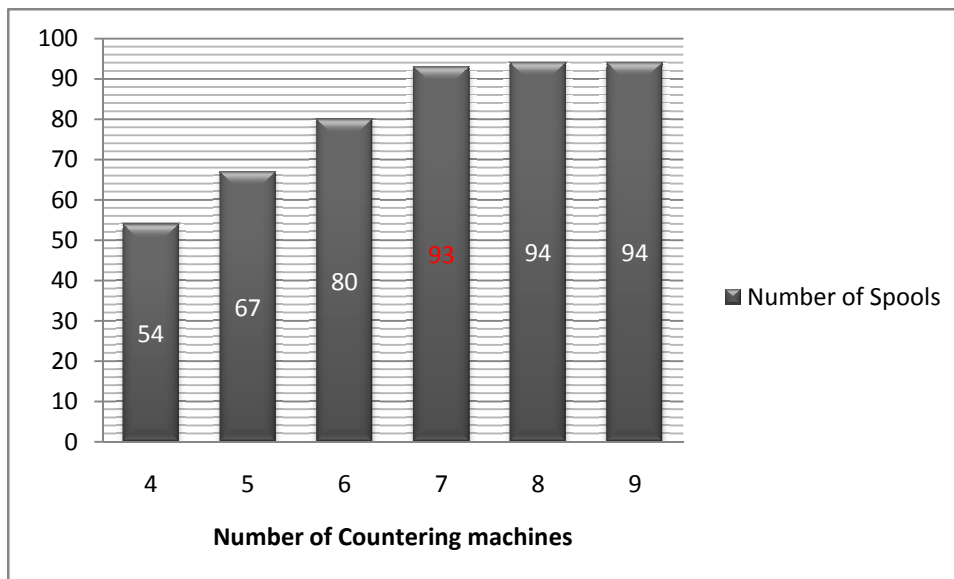


Figure 14 Output vs. Counteracting Machines

The optimum result is 93 spools out. 8 or 9 counteracting machines would again become infeasible as the output doesn't increase drastically.

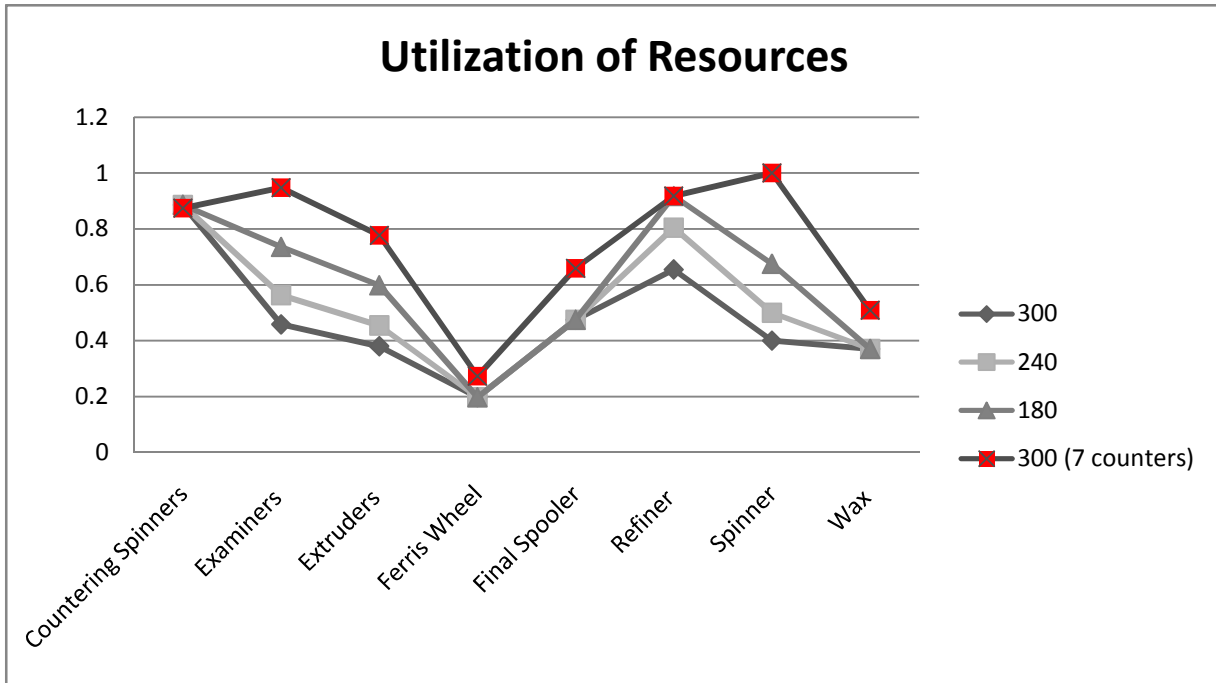


Figure 15 Future State Resource Utilization

Figure 15 shows that with the de-bottlenecking at the countering process leads to a great overall improvement of resource utilization.

Future State Map

A buffer will be used at parts waiting for countering. Good signaling and communication will be done between production control, countering and spinning (which is the drum of the production line). Waiting times have been greatly reduced by keeping inventory lower and by extending the inter arrival time of the raw material that starts at the spinning process.

Future State Value Stream Map

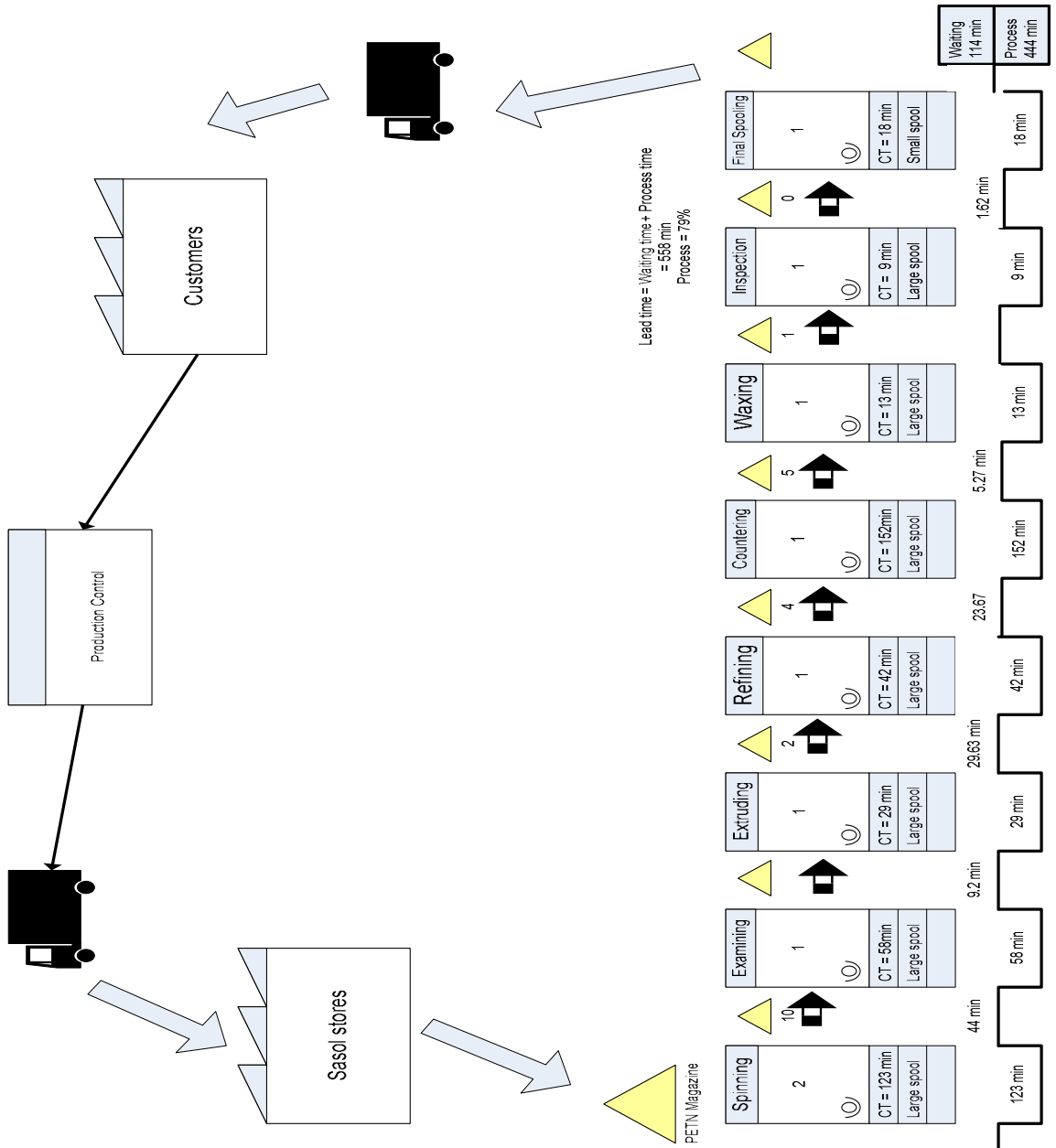


Figure 16 Future State VSM

Final Proposal

The goal of the project was to optimize the production line and to identify bottlenecks. The final proposal is based on the findings found by the future state simulation model.

The counterering process has been identified as the leading constraint throughout the whole process. It was shown that by increasing the number of counterering machines, a higher production output can be achieved (34% increase in throughput). This leads to an entire new project of calculating the feasibility and cost of such an implementation.

Conclusion

As the process is almost entirely automated, the current state of the operator utilization is adequate. Big decisions need to be made if the throughput of the process is to be increased drastically, as this will only be generated through capital investments. A drum-buffer-rope system will decrease the inventory and eliminate non-value-adding waiting time.

At the very least, the project can eliminate excess inventory and at the very most, increase productivity. A basis has been created for further decisions to be made for the productivity expansion of the entire plant.

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Appendices

Appendix A: Screen shot of simulation model

