THE IMPROVEMENT OF A SEAT MANUFACTURING LINE AT AEROSUD (PTY) LTD.

BY

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Abstract

THE IMPROVEMENT OF A SEAT MANUFACTURING

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Aerosud Aviation Pty (ltd) is a large company which manufactures aircraft interiors and other products. Aerosud has a manufacturing line that manufactures seats and is at present struggling to keep up with demand. Given the current economic crises, companies are looking to cut any non-value adding processes, projects, and expenditures. Taking this into account, along with the fact that the seats manufacturing line is struggling to keep up with demand, Aerosud needs to increase their return on investment by improving the production line.

Aan Oom Albert, Tannie Erna en Madalè, wie se gasvryheid en liefde ek nooit sal vergeet nie..

"...if we love one another, God abides in us

and His love is brought to completion in us."

1 John 4:12b

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Section I

Introduction & Background

1.1 Company Background

Aerosud was formed in 1990 by the then key designers of the South African Rooivalk Combat Support Helicopter, together with similar leaders from the Cheetah fighter program (Mirage III upgrade) and the Product Support Environment. The first major contract involved the re-engineering of the Mirage F1 Fighter with the Klimov RD33 engine used in the Mig 29 fighter. Towards 1995 Aerosud embarked on diversification into the commercial aviation market with the design of galleys and other interior systems. Today, Aerosud is an internationally recognised supplier for interior systems.

Around 2000 Aerosud embarked upon major expansion of its production capacity. They now manufacture around 2000 parts and assemblies a day, from their new premises near Pretoria, and supply these to the assembly lines of Airbus, Boeing, BAE Systems, Agusta Westland Helicopters and Spirit AeroSystems. Today, deeply involved in both Civil and Military Aviation Engineering projects, Aerosud's activities cover design, development, prototyping, manufacturing and service support. Aerosud has become an established leader in the South African aviation industry and is increasingly being recognised as a respected brand name in the very competitive international marketplace. Aerosud is situated on Corner of Van Ryneveld Ave & Van Der Spuy Str in Pierre Van Ryneveld, Pretoria. Currently there are more than 600 employees working at Aerosud.

Aerosud's product range includes the following: Electronic Warfare, Aircraft Refurbishment, Ancillary Systems, Galley Refurbishment, Seat Partitions, New Galleys, Structural Assemblies, Metallic Parts and Welded Assemblies, Interior Parts and Assemblies and A400M Development

1.2 Problem Background

The main problem with the seats manufacturing line is that it is struggling to keep up with demand. A year ago only three seats were required per week and this was done with little difficulty. At present the demand has been pushed up to four seats per week, which leads to overtime as they get closer to the shipping date.

The project will need a lot of research and study, creative thinking and analytical problem solving, along with spending time and working with skilled workers and artisans. The manufacturing line consists of the following basic processes:

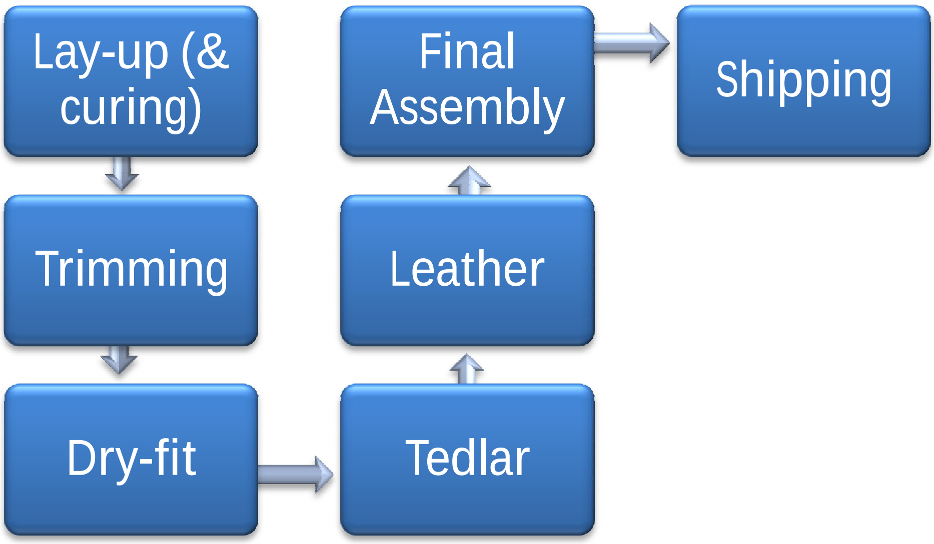


Figure 1: Process flow diagram

1.3 Project Aim

The goal of the project will be to help the manufacturing line meet future demand on time and seek opportunities for current improvement.

Objective 1

Study and analyse the manufacturing line to obtain the current state of the system.

Objective 2

Perform relevant research and seek a conceptual solution for the current state problems.

Objective 3

Create a proposal which focuses on handling future demand increases.

1.4 Project Scope

Boundaries of the project:

Included:

- All processes and resources participating in the manufacturing of the seats.
- When looking at operating expenses, the main focus will be to lower the total amount of man hours spent on a project, in other words, do more work in less time because man hours take up 70% of the operating expenses.

The project will cover the whole process, from where the raw materials are transformed into parts, to assembly where the different parts are put together.

Excluded:

- Material shortages
- Infrequent breakdowns
- Supplier problems
- Inbound and outbound logistics

Presently there are no real problems in terms of suppliers, material shortages and breakdowns, nor have their been in the past, so they will not be part of the project. A breakdown in a manufacturing line differs from process to process and by including the infrequent breakdowns in the simulation model, more accurate solutions will not be achieved.

1.5 Deliverables

The deliverables of this project will be a current state analysis and a future state proposal. The current state analysis will aim to show that the current setup can deliver more with a few minor changes. The future proposal will be a re-arrangement of workers along with improvements on the manufacturing line to cope with an increase in demand.

Section II

Literature Review

Theory of constraints, Lean manufacturing and Simulation Modelling were researched for the literature review. Theory of constraints and Lean manufacturing are two of the philosophies being used in business and especially in manufacturing today. As in Figure 2, a manufacturing system is composed out of inputs, outputs, external factors and internal factors and because of the complexity of most systems, they need some sort of controls or a set of rules which brings these processes inside the system together in harmony to produce the desired outputs.

Theory of constraint and Lean manufacturing are two such “set of rules” that help a business to run like a good oiled engine. Both philosophies are big and complex and has a lot of different tools which are used to improve the current processes. For Theory of constrains, Five focussing steps and Drum-buffer-rope were looked at and for Lean manufacturing, Seven wastes and Value stream mapping.

The goal is to find a combination that suits Aerosud’s environment the best.

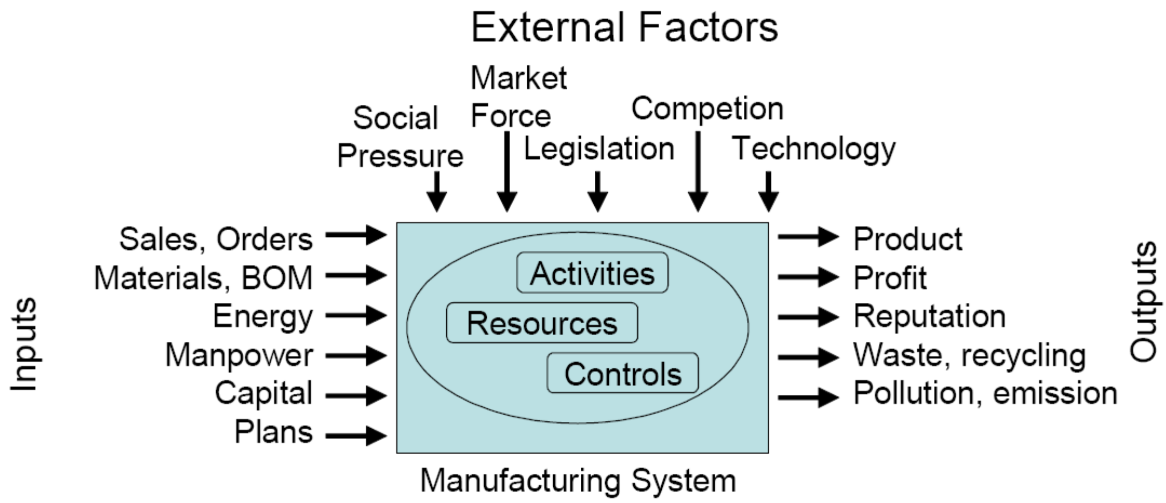


Figure 2: Manufacturing system

2.1 Theory of Constraints

History

“*TOC is a multifaceted management philosophy, which emerged in the 1980s.*” (Mabin and Balderstone, 2000). In a book on Theory of Constraints, McMullen (1998) says that the question “Where did TOC come from?” has five answers:

1. Eliyahu M. Goldratt was the originator.

2. TOC was there all along waiting to be discovered.
3. Parts of TOC were discovered by lots of people.
4. Many people worked with Dr. Goldratt on developing theory of constraints.
5. Graduate students helped invented TOC while working with Dr. Goldratt.

In short, all the answers are correct. Dr. Eliyahu M. Goldratt author of numerous books like "The Goal" is the mastermind behind the theory of constraints and has been the leader and has done the majority of the work (Mabin and Balderstone, 2000). Dr. Goldratt has used scientific methods to create concepts in management that have proven to be of great value to the industry, he has been able to encourage and inspire others to use scientific thinking methods in their personal and professional lives (McMullen, 1998).

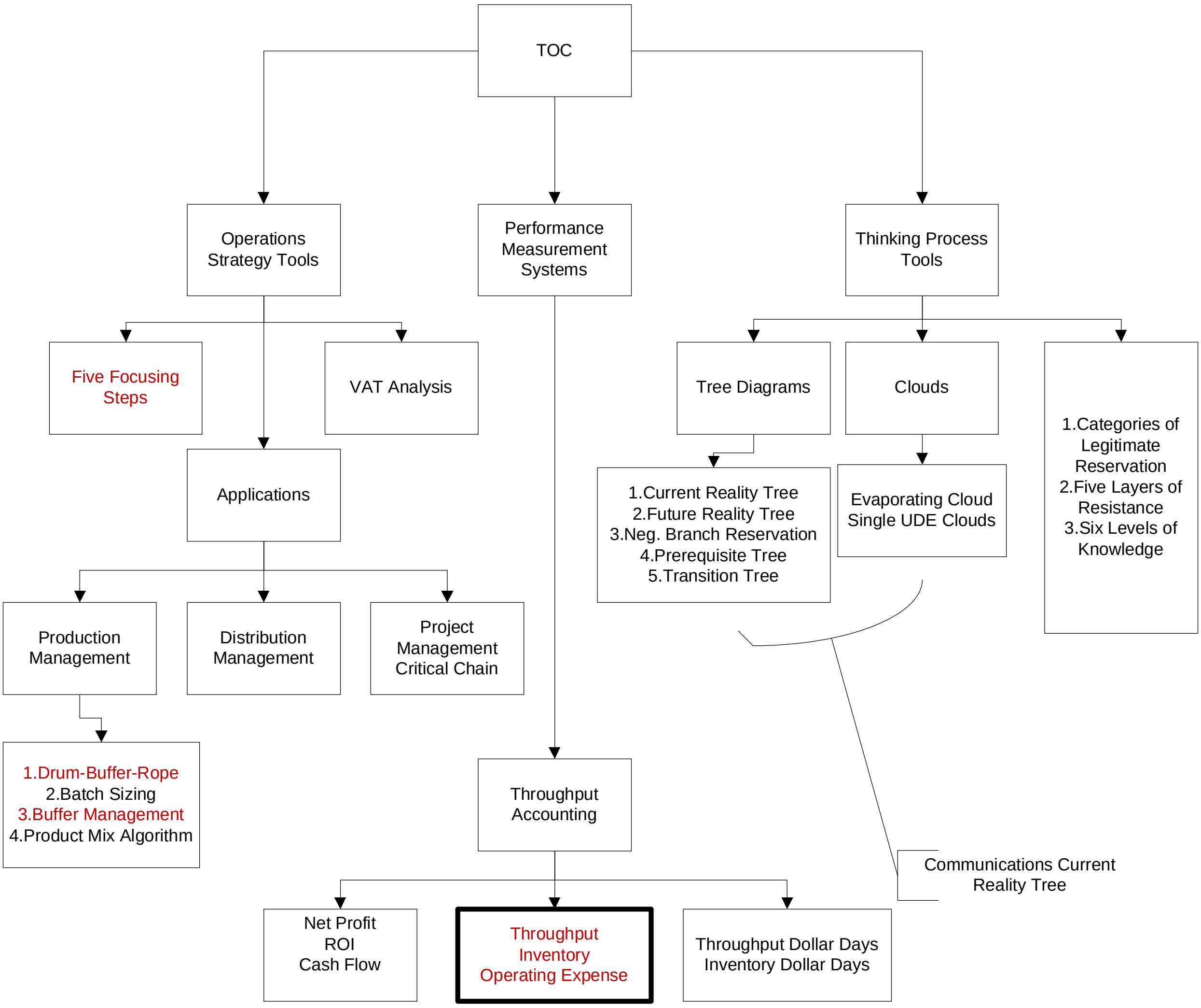


Figure 3: Mabin and Balderstone (2000) The Theory of constraints

Application

According to Cox and Spencer (1998) there are two fundamental questions that need to be answered for a successful management today: (1) *what is the real goal of an organization* and (2) *what is the performance measurement system that will support the attainment of the goal?*

In the third edition of The Goal by E. M. Goldratt (1985) it is reported that the goal of a firm is to "make money now and in the future". There are three financial measures of a firm's ability to make money: (1) *Net profit* – an absolute measurement in dollars, (2*) Return on investment* – a relative measure based on investment and (3) *Cash flow* – a survival measurement. These financial measures operate well on management level, but on operational level we need another set of measurements (Chase, Jacobs & Aquilano, 2006). Goldratt developed three measures for shop floor managers to use in their day-to-day operational decisions: Throughput, inventory and operating expense. Goldratt defines these measures for us in terms of the goal of a firm, making money now and in the future and we obtain them from Cox and Spencer (1998):

Throughput: The rate at which the organization generates money through sales.

Inventory: Items purchased by the organization for resale, valued at the purchased price to the firm.

Operating expenses: The amount of money spent by the organization to convert inventory into throughput.

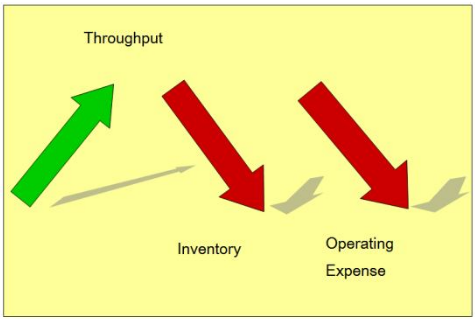


Figure 4: Chase et al (2006) Operational goal

Figure 4: Chase et al (2006) Operational Goal

Theory of Constraint's Five-Step Focusing Process

"*The five-step process…can be used in any situation. It is used in strategic planning, project management, process improvement, manufacturing continuous improvement, and day-to-day factory scheduling*." (McMullen, 1998)

1. Identify the system's constraints.
2. Decide how to exploit the constraints.
3. Subordinate everything else to the above decisions.
4. Elevate the constraints (Increase capacity).
5. Return to step 1 and don't let inertia become the new constraint.

Spencer & Cox (1998) confirm that "(t)he five–step process has applicability in manufacturing and service activities." Later they finalize that "(t)he key contribution of the five-step process is the identification of the resources that, when managed correctly, can the highest productivity gains for the organization. Improvement efforts can then be focused on these resources."

The five step focusing process can be seen in appendix D.

Drum-Buffer-Rope-Scheduling

"Every production system needs some control point or points to control the flow of product through the system. If the system contains a bottleneck, the bottleneck is the best place for control. This control point is called the drum because is strikes the beat that the rest of the system (or those parts that it influences) uses to function." (Chase, Jacobs & Aquilano, 2006).

A bottleneck is defined as a resource or process that doesn't have enough capacity to meet the demand and for minimum lead time this process or resources needs to be utilized 100% of the time. There is also a "capacity controlled resource" or a "CCR", this is a resource that operates near full capacity and if there is no bottleneck then this is the next best place to set the drum. Chase et al (2006)

Chase et al (2006) motivates that there are 2 things that can be done with a bottleneck:

1. Keep a buffer inventory in front of it so that it always has parts to work on.
2. Communicate (rope) upstream so that they do not produce more, this will keep inventory from building up.

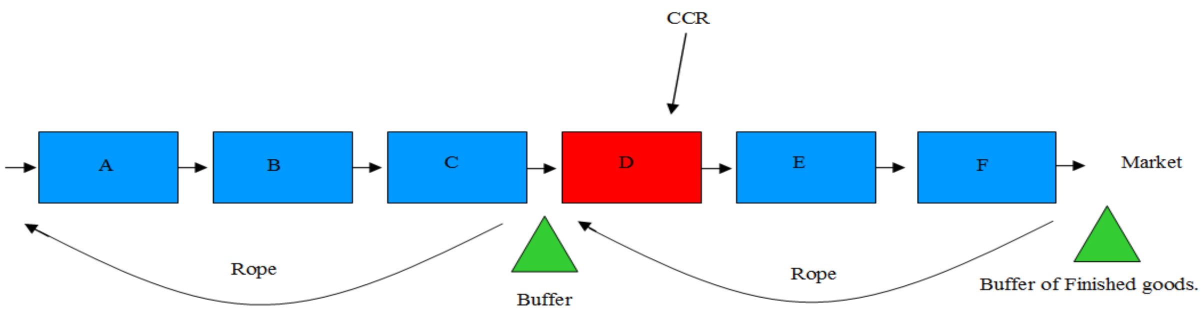


Figure 5: Chase et al (2006) Linear flow of product with a capacity-constrained resource

1. Do not balance capacity—balance flow.
2. The level of utilization of a nonbottleneck resource is determined not by its own potential but by some other constraint in the system.
3. Utilization and activation of a resource are not the same.
4. An hour lost at a bottleneck is an hour lost for in the system.
5. An hour saved at a nonbottleneck is a mirage.
6. Bottlenecks govern both throughput and inventory in the system
7. The transfer batch may not and many times should not be equal to the process batch.
8. A process batch should be variable both along its route and in time.
9. Priorities can be set only by examining the system 's constraints. Lead time is a derivative of the schedule.

Figure 6: Goldratt's Nine rules of production scheduling: (Chase et al, 2006)

Conclusion

The goal of any firm as defined by Goldratt (2004) is to "make money" and in order for the system to control throughput, inventory, and operating expense, the whole system must be analyzed to identify bottlenecks and capacity-constrained resources. Chase et al (2006) concludes that "*the measurement system within a firm should encourage the increase of net profits, return on investment, and cash flow. The firm can accomplish this if, at the operations level, it rewards performance based on the amount of throughput, inventory, and operating expense created. This is essential for a firm's success.*"

2.2 Lean Manufacturing (Just-in-Time)

History

"*The most significant production management approach of the past 50 years is lean or just in time (JIT) production*." (Chase et al, 2006)

JIT became world renowned in the 1970s but we see Henry Ford using JIT concepts after the turn of the century and the Japanese in the 1930s. Tai-ichi Ohno of Toyota Motors used JIT to excel Toyota to the forefront of time and quality in the automotive industry. In the 1990s the term lean had appeared because of JIT's emphasis on eliminating waste throughout the manufacturing and operating systems. (Chase et al, 2006).

Application

Goddard (1986) defines Just-in-Time as follows:

"*An approach to achieving excellence in a manufacturing company based on the continuing elimination of waste and consistent improvement in productivity. Waste is then defined as those activities that do not add value to the product."*

JIT in a nutshell is producing what is required *when it is required* and nothing more (Chase et al, 2006). This "when required" means that when a customer orders a product, only then is the product required. This is in general called a "make-to-order" process and helps keep inventory (both work-in-process (WIP) and finished goods) at a minimum, which is actually by definition a pull system, one of the character traits of a JIT system. Lean manufacturing is an integrated set of activities designed to gain high volume manufacturing while incorporating low levels of inventories of raw materials, work-in-process, and finished goods (Chase et al, 2006).

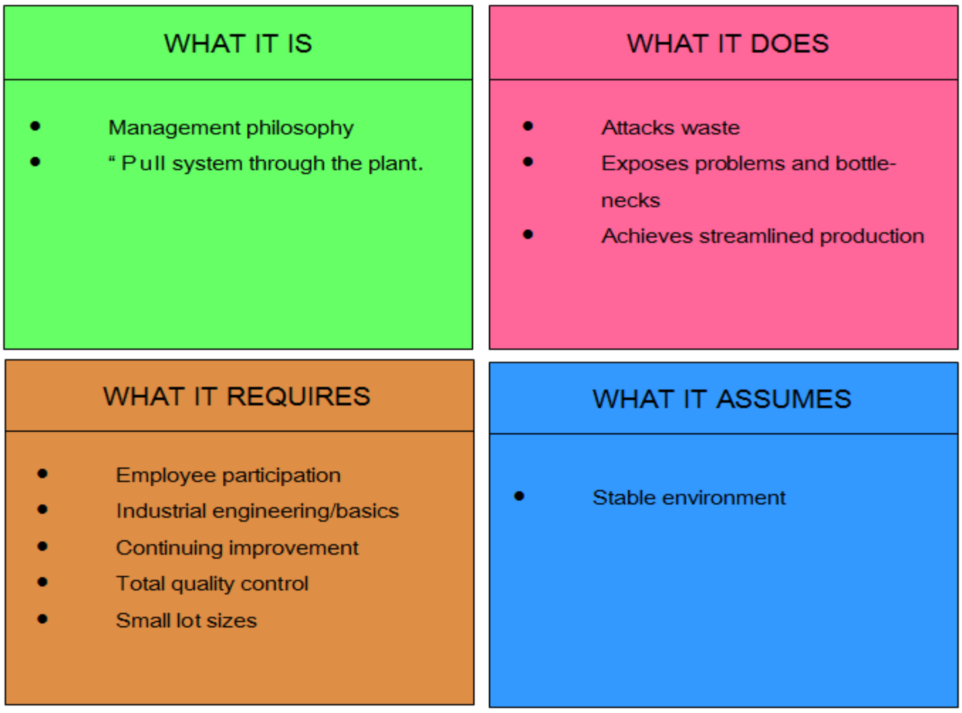


Figure 7: Chase et al (2006) Features of Lean production

The Toyota Production System is the benchmark in terms of lean manufacturing and it was developed to improve quality and productivity and is based on two philosophies that are central to the Japanese culture: elimination of waste and respect for people (Chase et al, 2006).

There are 7 prominent types of waste as defined by Fujio Cho: (1) waste from over production, (2) waste of waiting time, (3) transportation waste, (4) inventory waste, (5) processing waste, (6) waste of motion, and (7) waste from product defects. Value stream mapping is a tool that is used more widely for eliminating waste (Chase et al, 2006).

Value Stream Mapping

Jones and Womack (2000) define value stream mapping as 'the simple process of directly observing the flows of information and materials as they now occur summarising them visually and then envisioning a future state with much better performance'. This helps in planning and linking lean initiatives through systematic data capture and analysis. This unique mapping concept helps to visualize the station cycle times, inventory at each stage (WIP), manpower and information flow across the supply chain. The current (or 'as is') state is mapped to capture a snapshot of how things are done and where the improvement potential lie. Future or 'to be' state map is also drawn to show how things should to be done considering takt time requirements (Seth, D. & Gupta, V., 2005). Takt time is a German word musical meter and it refers to pacing work according to customer demand (Chase et al, 2006).

Chase et al (2006) shows that there are seven elements that reduce waste:

1. Focused Factory Networks.

   Rather a few smaller plants than one big plant, this way operation stays easier to manage and control.

2. Group Technology.

   Similar parts are grouped and the processes used to make the parts are arranged in a specialized work cell.

3. Quality at the Source.

   This means to do things right the first time.

4. JIT Production

   Right part, right place, right time. When inventory is low, quality problems becomes visible.

5. Uniform Plant Loading

   Smoothing production flow. (Building the same mix of products every day in small quantities)

6. Kanban Production Control Systems

   Signaling device to regulate JIT flows.

7. Minimized Setup Times

   Because of the smaller lot sizes, there are a lot of setups to be done and they need to be done more quickly.

Advantages of Lean

- JIT reduces lead times and reduces WIP (Chase et al, 2006)
- Advantages of Reduced Order Quantity
- Reduced inventory.
- Improved product quality.
- Reduced space requirements.
- Increased capacity – if total setup times are reduced.
- Better use of equipment and labour.

Goddard (1986)

Draw backs

- JIT is limited to repetitive manufacturing
- JIT requires a stable production level (about a month long)
- JIT has low flexibility in terms of products produced. (Products must be similar with a limited number of options)
- JIT requires WIP when used with a kanban system, this is so that there is "something to pull".
- Vendors need to be located in the surrounding area with fast access and small transport times because of smaller more frequent deliveries.

Goddard (1986)

Conclusion

Chase et al (2006) states: "*...lean production has proven its value to thousands of companies throughout the world."* They conclude that: "*Lean production is an encompassing philosophy considering product design, process design, equipment and facilities design, supply chain coordination, job design, and productivity improvement. If there is one "key" to successful implementation of lean or its variants, it's adopting a holistic approach, which according to a study by UK's McKinsey Production Centre, 'transforms not just the technical production system, but also the company's management system using a comprehensive change management process."*

2.3 Simulation Modelling

History

Simulation is not a new concept, and in the beginning it was done by hand. Around 1733 a man named Georges Louis Leclerc described an experiment to estimate the value of π and in the late 1920s statisticians began to use random-number machines and tables in numerical experiments to assist them develop, improve and comprehend statistical theory. So simulation is not a new method or tool and has been with us for a long time. Simulation really came in the spot light as digital computers appeared in the 1950s and 1960s, programs were written in general-procedure languages like FORTRAN to do simulations of more complicated systems. Special-purpose simulation languages like GPSS, Simscript, SLAM, and SIMAN showed up on the scene later on and provided a much more solid framework for the different types of simulations that people do. So here we are today and simulation is still very popular and evolving all the time although it is still very time consuming to learn a specific language. There are some products that are easy to use; they are referred to as high level “Simulators”. Arena is one such tool (Kelton, Sadowski & Sturrock, 2007).

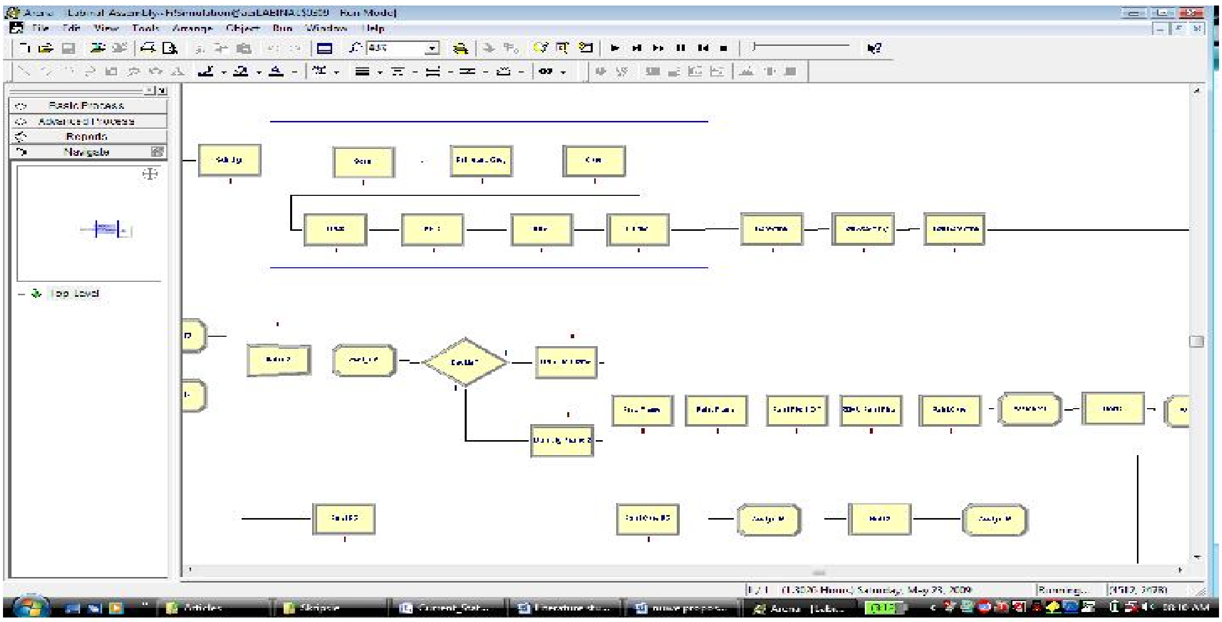


Figure 8: Arena simulation software

Definition

Depending on its application, the word simulation can have many definitions but in business, it normally refers to using a computer to do experiments on a model of a real system (Chase et al, 2006).

Different Kinds of Simulations

Kelton et al (2007) classifies simulation models in three dimensions:

Static vs. Dynamic

Most operational models are dynamic and with static models, time doesn't play a role.

Continuous vs. Discrete

In continuous models the state of the systems continuously changes over time where as in a discrete system change can only occur at separated points in time. You can have elements of both in a model, and then it is called a mixed continuous-discrete model.

Deterministic vs. Stochastic

In a deterministic model every input is certain and in a stochastic model there are at least some random inputs. A model can have both in different components, deciding which must go where is dependent on the level of realism.

Advantages/Popularity of Simulation

One of the advantages of simulation is its ability to simulate or deal with very complicated models of complicated systems, in other words, it's a quite powerful tool. As computers get faster and cheaper, it gets easier and much more cost effective to implement simulation tools. With the advance in software and high level programming it is a good tool for fast and valid decision making (Kelton, 2007).

Disadvantages

Random inputs in stochastic models give random outputs and the model has to be simulated a lot of times, its sometimes difficult to determine how many times especially if the model stops at a particular point (for instance, a bank is open from 9 to 5), so running it longer to average out the output is inappropriate. A good thing about simulation, especially on software like Arena, is that you can simplify the model and all aspects of it; the bad thing about this is it might not be a valid or correct representation of the real system. (Kelton, 2007).

Application

Furthermore, we propose that there may be cases, as was found in this application, where simulation is not just feasible in the same time frame as the use of VSM, but is, in fact, important to provide information about the dynamic nature of the production process. This type of information cannot be obtained using VSM alone because of the static nature of this tool. Arena® performs discrete event simulation (Kelton *et al.*, 1998) and was used in this application to simulate the future state of the AB product line. This case study application has demonstrated that simulation analysis can be a useful and important part of VSM. Although we are not proposing that simulation always be utilised with VSM, it can form an integral part of the tool set (S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler eds. 2008 Proceedings of the 2008 Winter Simulation Conference).

Conclusion

Simulation is not always the best or cheapest choice; Chase et al (2006) put it very well by saying: "…there are no boundaries to building a model or making assumptions about a system. Expanding computer power and memory have pushed out the limits of what can be simulated."

2.4 Literature Review Conclusions

Improvement of the production line requires the correct combination of tools discussed in the literature review. Simulation can be used in relationship with drum-buffer-rope and also with the value stream mapping incorporated to eliminate waste, all in all to get a more accurate future state. Goldratt's measurements can be incorporated to regulate each decision and the five focusing steps to continue improvement. This will give a good all round lean and TOC foundation for improvement and the desired future state.

2.5 Development of Conceptual Design

For the conceptual design, a mixture of the literature reviewed will be gathered and arranged so that the tools, methods and philosophies grouped together can complement each other. The goal or objective of the design is to find the correct tools to improve current system and find a desired state.

From the current state all necessary data needs to be collected for the VSM so that a current state value stream map can be drawn of the system. Then a simulation model of the system can be simulated in Arena, guided by the five focusing steps with Goldratt's three measurements (throughput, inventory and operating expense) in mind the correct improvements can be made continuously. Man-hours makes up 70% of the operating cost on the line, the lean principles will work especially well to decrease the lead time which will in turn decrease the man-hours.

A visual representation can be seen from Figure 12 as it shows VSM, seven wastes and simulation being utilized from the current state to the future state with the five focusing steps and Goldratt's three measurements to guide the decisions being made.

The conceptual design presented will lay a good foundation for improvement and with Lean and TOC to fall back to for guidance, an attainable future state will be reached.

2.6 Conclusion

It cannot be expected of a tool, method or theory to give the same result in reality as in textbooks; there are a lot more factors which needs to be taken into consideration. Despite this, the literature review hopefully proved and showed that with these methods and tools that a difference can be made and that the new conceptual design will bring the company closer to its goal: To make money.

Section III

Current State Analysis

3.1 Background

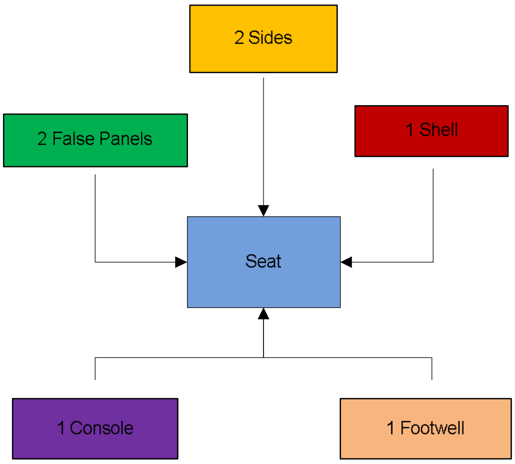


Figure 9: Main parts of an assembled seat

Aerosud produces four seats every five days. The assembled seat consists out of five main parts: A shell, two sides, a footwell, a console and two false panels (Figure 9). All parts are made at Aerosud and only the raw materials are bought in from outside suppliers. The shell, two sides and the footwell are manufactured on the same production line while the other components are produced in another department. The shells and sides run on the same manufacturing line with the consoles, false panels joining the system at Leather and footwells joining at the last stage, assembly. Figure 10 shows a process flow.

Data, insight and ideas were all gained on the shop floor (in the factory). Ample time was spent on the shop floor learning the processes, tasks and mentality of the workers. The workers know their tasks and the entire process very well. Consequently, almost all improvement ideas can be acquired from these workers by just listening to them, asking for their advice and queries about the seats. By being humble, positive reactions occur more frequently.

Figures 10 and 11 show all the processes, workers, their different tasks and process times. Although the diagrams appear to be simple, it demanded a vast amount of time and asking of the right questions to gain the data and process it into logic, useable information. The simulation was built using the information seen on the diagrams.

3.2 Process Flow & Manufacturing Process

The manufacturing process starts at Lay-up where material is laid up in moulds which goes into an oven to cure. The following morning the parts are removed from the moulds, numbered and taken to Trimming, meanwhile the consoles and false panels are being made in another department.

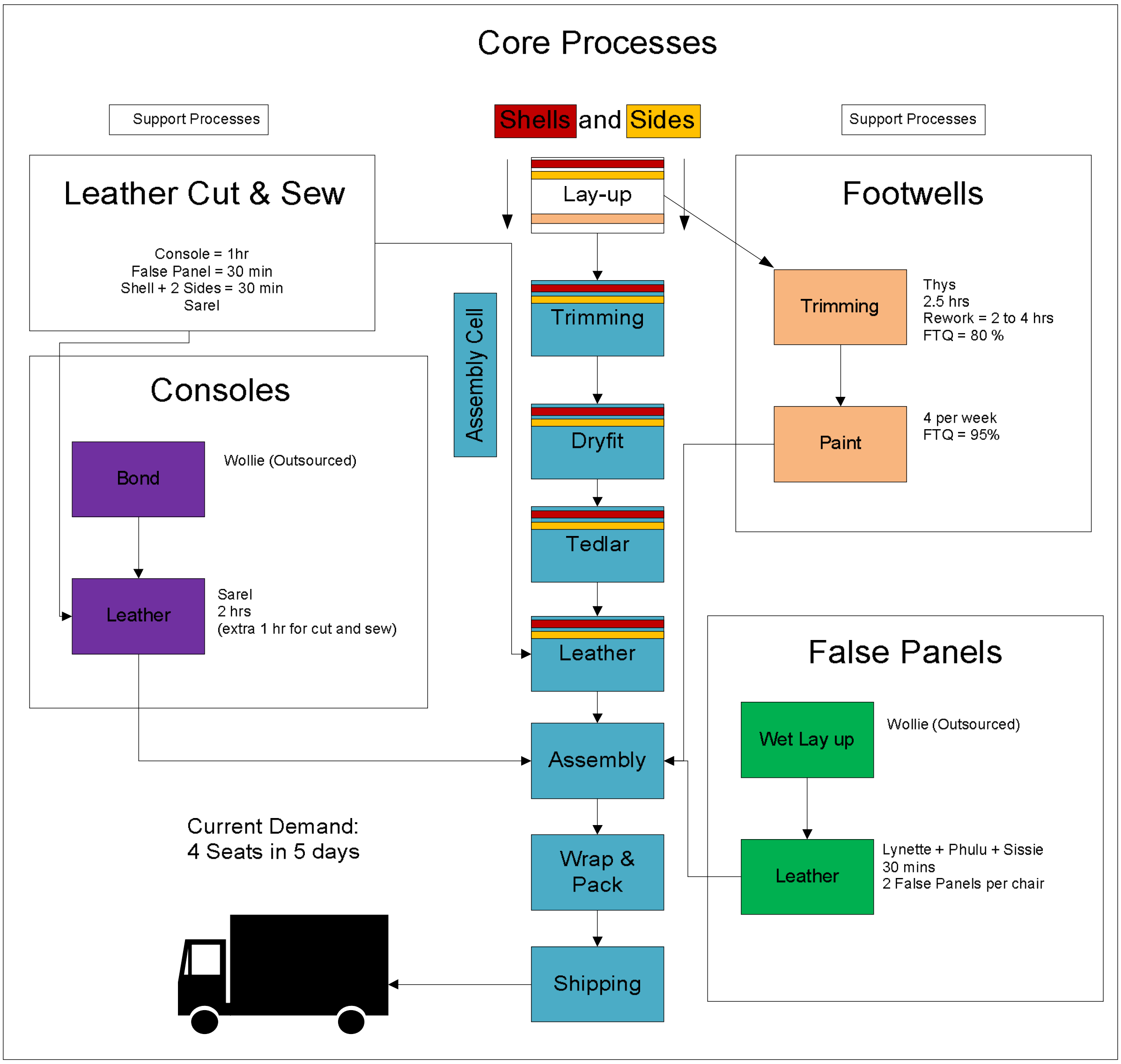


Figure 10: Core & support processes

At Trimming, the surface of the parts is sanded until it is extremely smooth. Then the two sides and the shell are fitted on a jig like a puzzle to see if they fit. Every corner and edge where the sides and shell touch needs to be perfect. Normally filler is used to make the parts fit. Then the parts move on to receive a layer of material called tedlar; it is applied on the outside using a machine that heats the material and then sucks it onto the surface of the part with a vacuum. After Tedlar, leather is applied on both the insides and the false panels. Consoles also join the production line here. At Assembly the footwells join the process and all the parts are put together. The seats are ‘wrap packed’ and ready to be shipped at the end of the week. Figure 11 shows the shells and sides’ process flow in more detail. This is the current configuration of workers and processes. Every process except for the Tedlar is done by hand and requires little or no setup.

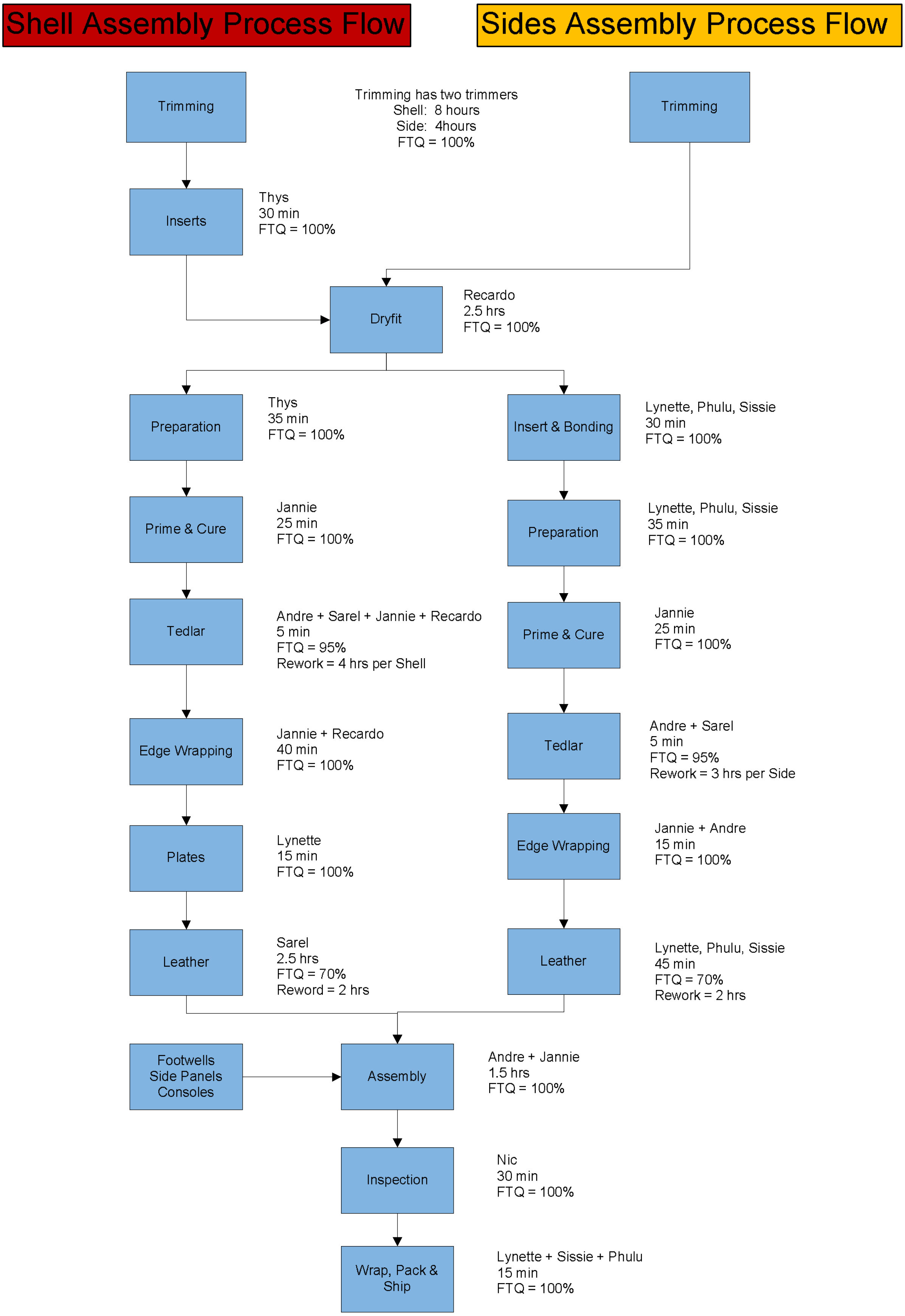


Figure 11: Shell & sides process flow

3.2 Responsibilities & Departments

The main production line (shells and sides) consists of two departments: Lay-up and Assembly.

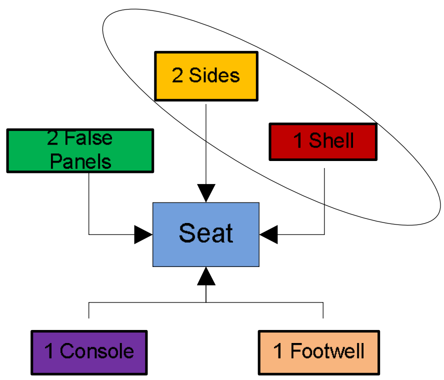
Lay-up produces parts for Boeing and seat parts for Sishuan, Comet, Avianca and Hinen. There were a number of different types of seats that Aerosud had to produce and all were created using the same moulds and oven. The work that Assembly does on these seats are almost identical, meaning that all the processes, material and the number of workers required, are the same. The only difference is that consoles are not required for all types of seats.

The Assembly cell stretches from Trimming to Assembly and this is where the parts spend most of their time before they are shipped.

All the tasks are illustrated in the diagram on the previous page. The Assembly cell leader, Andre Human, is responsible for a large amount of administration throughout the day. He has to ensure that the production line runs on schedule, so although he has the least direct process time, he is still extremely busy. Andre is responsible for resolving day-to-day problems and has to report to management, seeing as he is the person held accountable when they fail to make a shipping date.

Scope

The focus of this project will be on the core processes (Figure 11) because this is the heart of the seat production line. In other words, the focus falls on the shells and sides. Some of the Assembly cells' workers do work on other selected parts like leather and trimming; this is included in the simulation model.



Continuous Flow

The manufacturing line doesn't have one piece continuously flowing through the system from process to process. The parts are delayed at some points because of certain elements; for example when a spray booth needs to be booked because other departments are using it as well. This means they have to spray all the parts simultaneously. Glue can only be mixed once for four parts before they go to Tedlar. Consequently there are a few hick-ups involved, but the Assembly team takes these constraints into consideration while they are working to ensure the timing is right.

3.3 Current State

At this stage the demand is four seats per week. Lay-up is producing one seat per day and Trimming takes 8 hours to process one shell and two sides. With the current situation there is a lot of inventory in the Trimming cell, which have already been trimmed. The general feeling is thus that Assembly is the bottleneck but this statement will be explored further in the document.

The current state value stream (Lay-up to Assembly) is documented by using Value stream mapping (VSM). The VSM shows measures like waiting time, process time, cycle time, batch sizes, first time quality (FTQ), number of workers, lead time, inventory level and takt time.

Takt time is a measure used to pace the production line.

$$takt\ time = \frac{available\ time}{demand}$$

$$takt\ time = \frac{5\ days}{4\ seats}$$

$$takt\ time = 1.26\ days\ per\ seat$$

The huge amount of waiting time (151.95 hrs) is mainly because of the level of inventory waiting at trimming. All of this inventory has already been processed and is waiting to go to the next process. The lead time shown on the VSM is the waiting time plus the processing time which is a little more than 22 days. In other words, it will take a seat at least 22 days from start to finish. This amount of inventory can also be seen as cash lying on the shop floor. This is one of the reasons why inventory is included in the "Seven wastes" of Lean manufacturing. Inventory also increases lead time, hides problems and causes cash to be tied up. In Aerosud's case, the inventory lies at trimming, which insists that trimming is the biggest constraint but most of the seats have been trimmed and are thus waiting to go to the next process. This insists that assembly is the biggest constraint and the fact that they only produce four seats in five days proves this, this is however only because of demand.

The big question is what will happen if the demand increases?

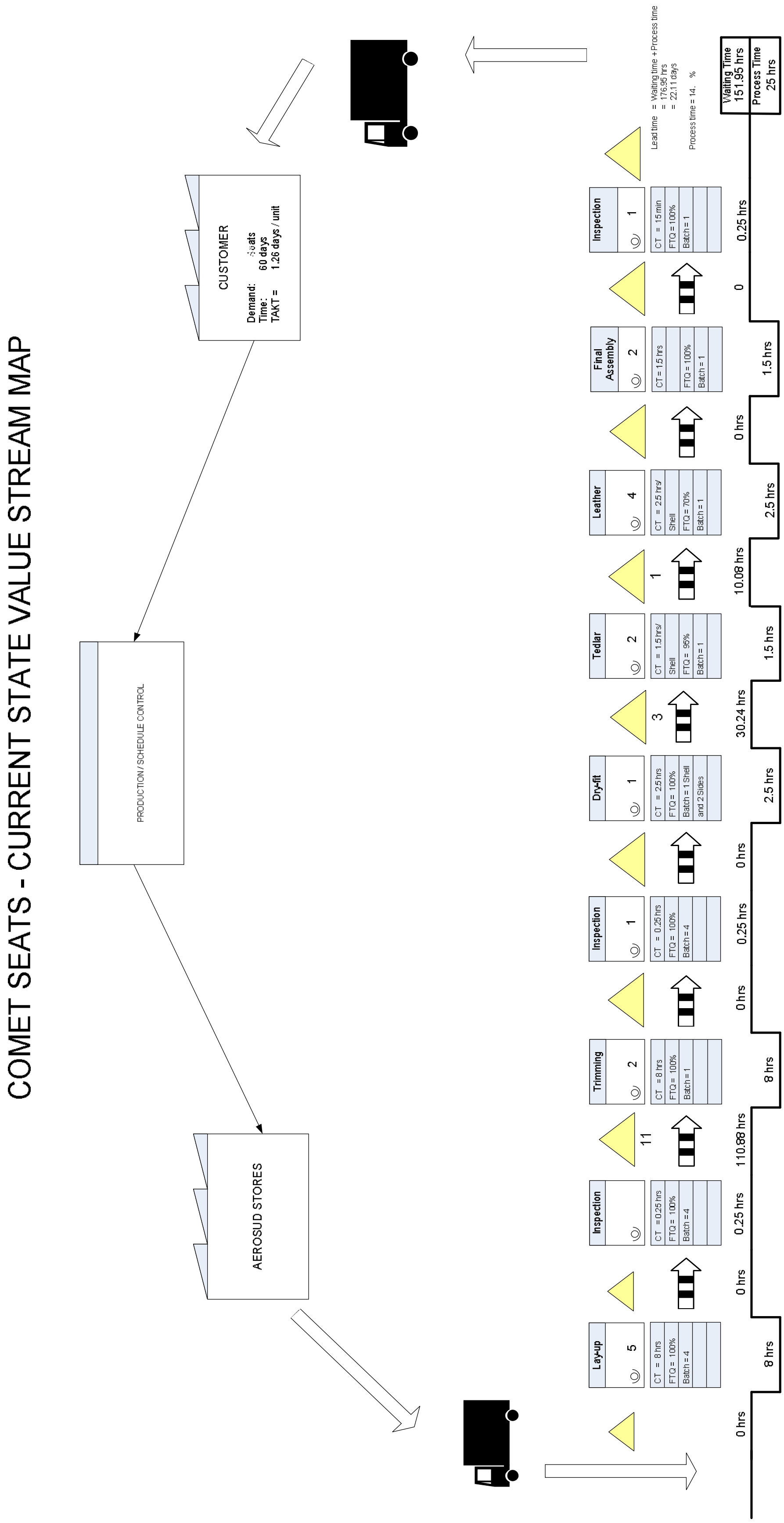


Figure 12: Current state VSM

3.4 Current State Simulation Modelling

The goal of the simulation model is to show where the bottleneck in the system lies and what will happen if demand increases. Continuous flow will also be looked at as it is not currently being achieved due to certain factors, this will be included in the future state.

Appendix A shows screen shots of the simulation model running from left to right, top to bottom.

Logic

In the bigger picture, the demand is 48 chairs in 60 days, so the model will run for 60 days. The workers spend 8.5 hours at work where 1 hour is subtracted for lunch and tea breaks and another half an hour for resting. So seven hours per day means the model will run for a total of 420 hours.

Demand will be regulated by the create modules. They are set to create parts (shell, two sides and a footwell) once every eight hours which means the inter arrival time (IAT) is set to eight and as the demand increases the IAT will decrease.

Scope

For demand increase to have an effect on the simulation model and for it to achieve its goal, certain parts are kept constant while others (normally one other) are changed. Lay-up and Trimming will be changed (as demand rises) while the rest of Assembly is kept constant. The reason for increasing both Lay-up and Trimming is because both their process times are the same. (Figure 12)

If the number of seats goes up, it means that Assembly (without Trimming) is not a constraint on the system (at the moment) and that the other one, or two of them, is the main system constraint.

Measures

A counter was inserted to count the number of finished seats that were produced. Waiting times of the entities in the queues waiting to be processed is used to see which processes delay the flow of parts the most. Resource utilisation (worker time utilisation) is also used to see which resources (workers) are being pushed to maximum capacity as the demand is increased. To conclude on the measures used:

Process measure: Waiting times of entities.

Resource measure: Resource utilisation.

System measure: Number of seats produced.

3.5 Analysis

Appendix B1 shows the data acquired from the simulation model which was put into a excel spreadsheet to compare the different reactions of the change in demand.

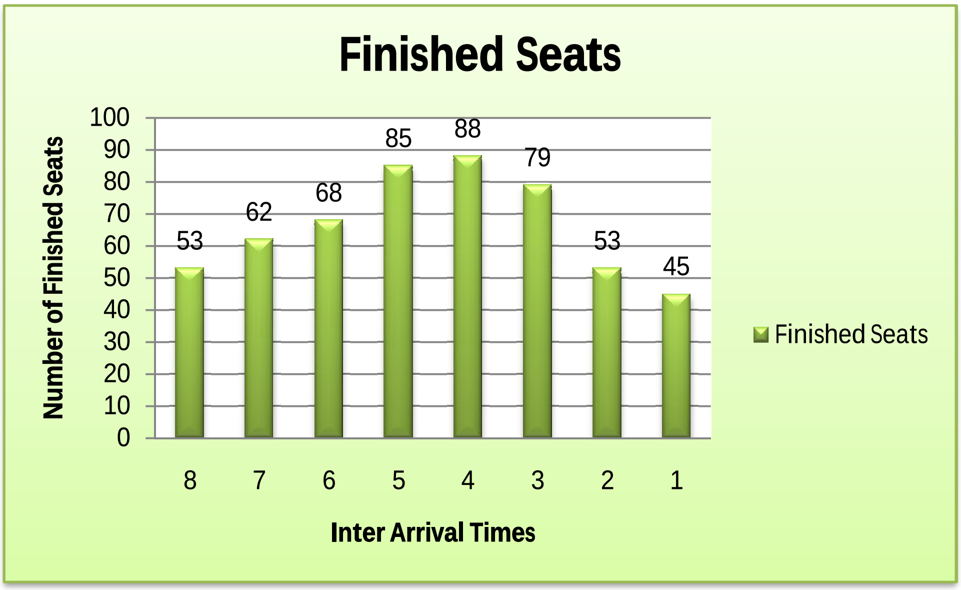


Figure 13: Finished seats for IAT (current state)

The simulation output from Figure 13 shows that with the current setup they must be able to produce more than 48 seats in 60 days. When the demand increases to more than 88 seats in 60 days, the Assembly cell can't handle it and some resources are over utilised.

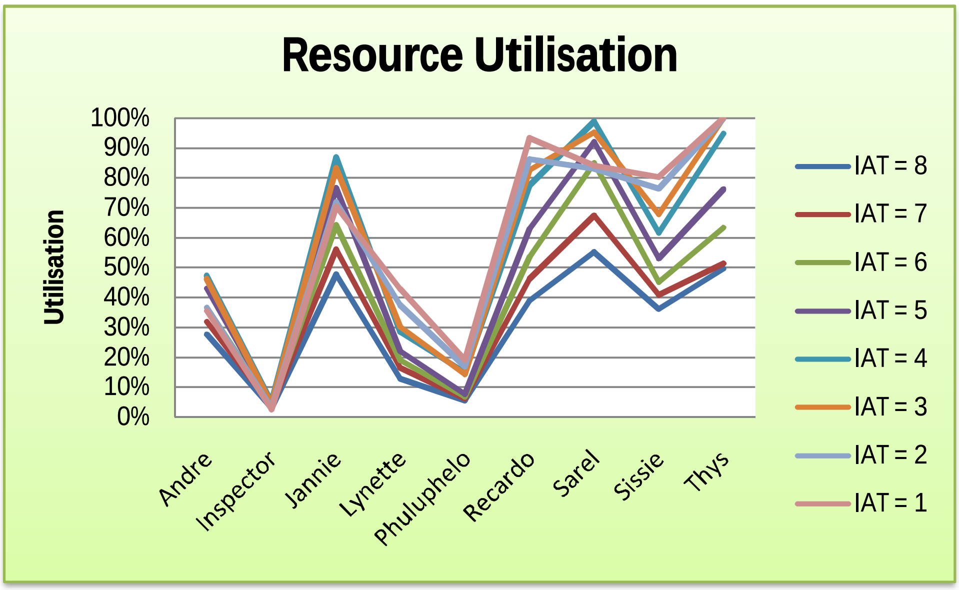


Figure 14: Current state resource utilisation

Some resources are heavily under- or over utilised and for the future, as demand increases, this can become a problem if not addressed correctly. Figure 14 shows that Jannie, Recardo, Sarel and Thys become over utilised when the arrival rate is too high. Figure 15 shows the current state with IAT equal to eight and the IAT where they produce 88 seats.

For the current state, producing 88 seats in 60 days is the limit, this means they cannot produce more than 7.33 seats per week. If it is achieved they will have improved by almost

200%. These resources or workers can be matched with process queues, which take very long.

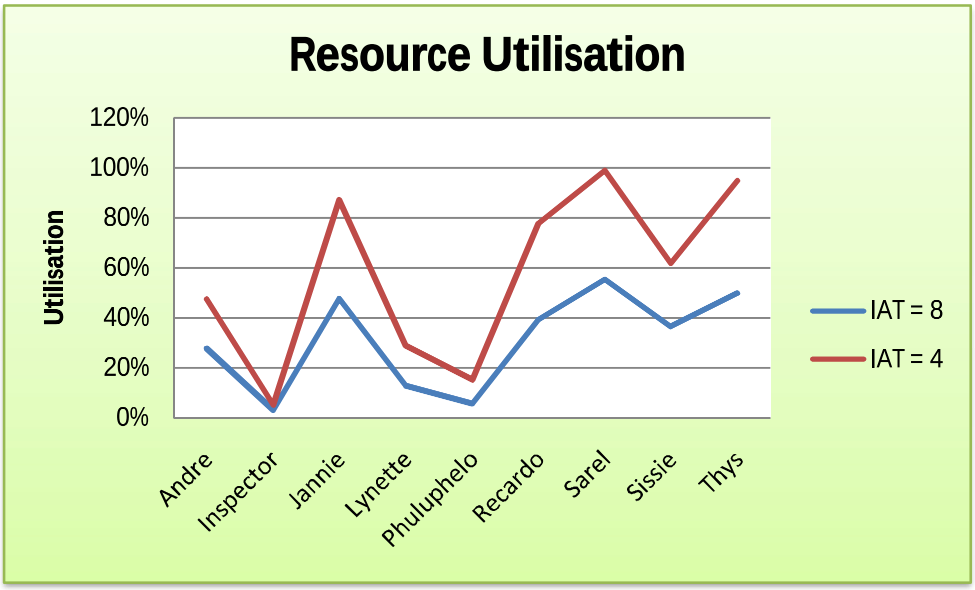


Figure 15: Resource utilisation for IAT of 8 & 4

Figure 16 highlights the longest process queue times. The original graph for the process waiting times can be seen in Appendix B2. Figure 16 shows IAT of eight and five, otherwise the axis is too big and finer details might be missed. The blue line represents the current state and shows three queues that are very long: the shell assembly queue, shell tedlar queue and side tedlar queue. These are, as previously explained, the areas where the parts have to wait for the rest of the set because of glue or the spray booth. As the simulation points out, it is in fact exactly the right areas.

The red line shows the waiting times for when, according to the simulation, the manufacturing line is operating near full capacity (for the current state). What is interesting is the fact that none of the former 'problem processes' grew in magnitude.

Output Conclusion

Analysis shows that the Assembly cell shouldn't have any problems dealing with the current capacity. Figure 16 teaches us that if the demand increases dramatically, the current combination or setup for the manufacturing line will not be adequate.

Practical Investigation

However, these findings need to be proven in reality. Luckily a random order for one seat arrived. This means that apart from the required four seats, an extra one needed to be assembled and the finding was that Assembly was able to handle the production rate. In theory this proves that Lay-up and/or Trimming are the real bottleneck areas.

Conclusion

The results have shown that if actual demand increases the Assembly cell will be able to manage it. Further analysis will be done to investigate if the capacity of Lay-up and Trimming can be increased. If so, the future state for the Seat manufacturing line can be improved.

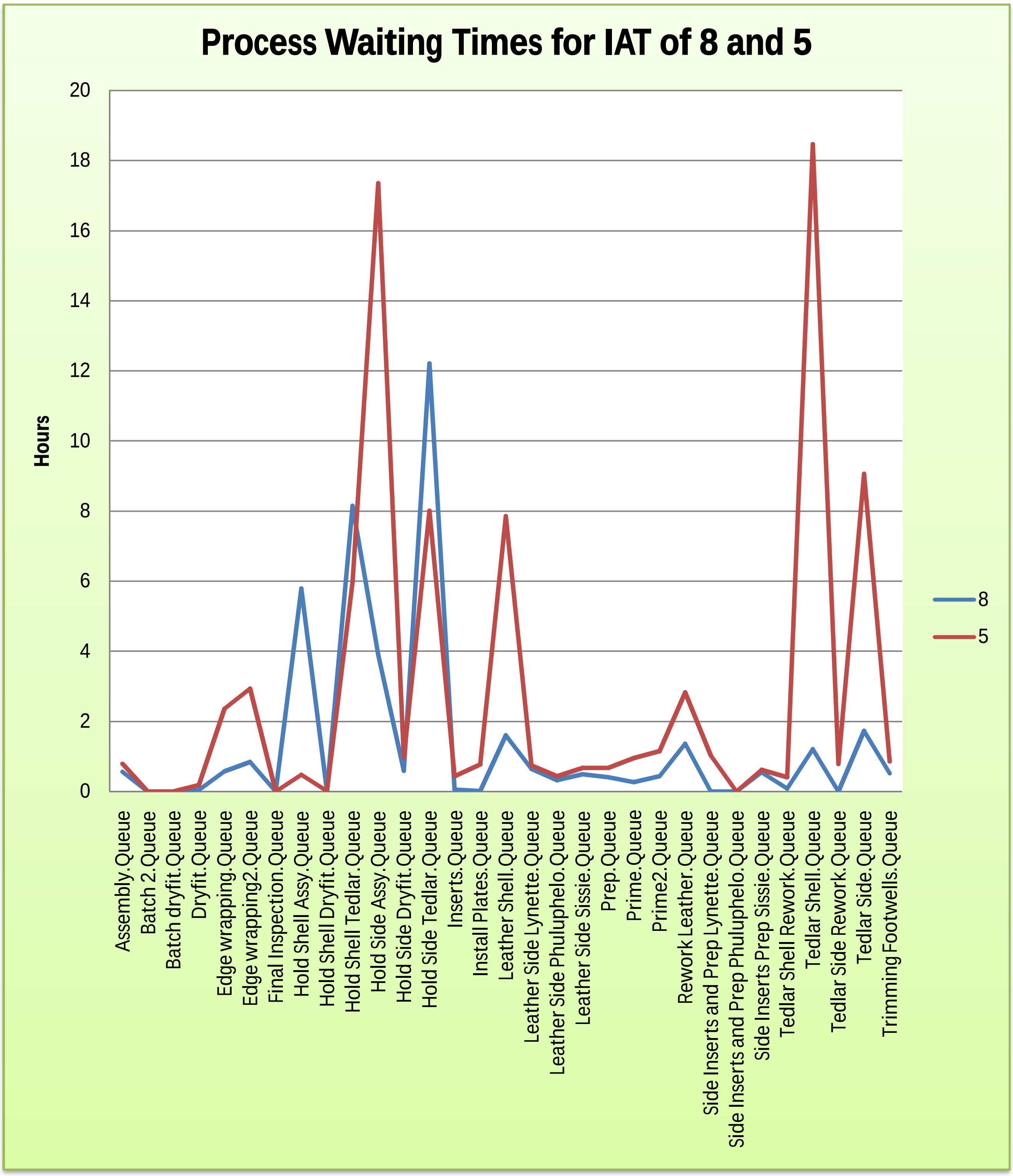


Figure 16: Current state process waiting times

3.7 Lay-up & Trimming

Both these processes' cycle times (operating times) are eight hours. The following are possible ideas for capacity increase:

Lay-up

1. Increase number of moulds
    a. An extra mould for every part means two seats per day. In a perfect system, this is 12 seats per week. There are several ovens on the premises if there is not enough space in the current oven.
2. Increase oven capacity
    a. If there is more space for curing, more moulds can be used.
3. Double shift (with extra moulds)
    a. The lay-up is done in one shift and then the moulds are left in the oven to cure over night. An extra shift will mean that while one set of parts are being laid-up in the mould, another is being cured.
4. Extra workers
    a. More moulds need more workers to do the tasks simultaneously.

Trimming

1. Extra workers
    a. Extra workers are an easy option, and the only constraint will be sanding tools and space. Fortunately there is enough unused space at Aerosud and the tools that the trimmers use are not that expensive. A cheaper alternative would be someone using normal sanding paper.
2. Better surface finish from Lay-up
    a. A better surface finish can cut down the trimming process time dramatically. There is a lot of sanding happening at Prep and this can be decreased as well.
        i. A better surface finish can be achieved by using higher quality materials or higher quality moulds. An alternative has already been tried in the form of a Teflon material that sticks on the surface of the moulds. This helps with a better finish,but the results of this will unfortunately only be seen in a few weeks time.
        ii. On a technical level, trimming can be viewed as a waste. It would not be necessary to perform this task if its preceding process was done perfectly. Another way of looking at it would be that trimming is work that has to be redone on the parts because Lay-up could not get the surface finish right the first time. One of the inspectors noted though, that it would be nearly impossible for Lay-up to produce a perfect surface finish.
3. Extra shift
    a. An extra shift will double the output

If the above changes are made, according to the results of the simulation model, the manufacturing line can achieve a throughput of 88 seats per week, which indicates a 183.33% improvement.

3.8 Current State Conclusion

The current state's improvement relies on the improvement of Trimming and Lay-up. To decrease the inventory that has been finished at Trimming, management only has to increase the production rate. This will then create a pull system, which will pull the inventory through the manufacturing line.

Assembly can deliver 60 days of work (48 seats) in 40.9 days which means 19.1 days of operating expenses can be saved. The total amount of working hours that can be saved add up to 1298.8 hours for every 48 seats.

To conclude, the seat manufacturing line, as it currently operates, will be able to cope with a demand of seven seats per week.

Section IV

Future State Analysis

In the previous section the real system constraints were identified and the improvement and savings potential were realised. The future state analysis will attempt to prove that if Aerosud accepts more projects and demand rises that it can be met by making improvements and changes to the manufacturing line.

4.1 Simulation Model

In Appendix C there are some general improvements that can be made to improve the production line.

For this simulation model the following realistic changes will be made:

1. Lay-up will produce up to 2 seats' parts per day.
2. The Teflon material added to the moulds decreases Trimming's and Prep's process times by 50%.
3. The Lay-up is done better which means the corners that were a problem when they where dry fitted, is sorted out. This saves an hour at Dryfit.
4. The resources will be moved to help and assist with different tasks when they have extra time to increase the resource utilisation of under utilised workers and decrease the process times.
    a. The resource utilisation and process waiting times graphs will help to decide which resources can be used more and which process needs more capacity.
5. A continuous flow environment will be assumed. This means glue can be mixed every time, spray booths are ready and there are enough necessary tools.
6. Lights will be installed at the Leather area which will eliminate the rework that has to be done.

4.2 Analysis

Data for the future state analysis can be seen in Appendix D1.

For the future state an extra IAT 3.5 was added to see if there can be any improvement in between IATs 3 and 4. An IAT of 3.5 means the manufacturing line produces two seats per day. From here on end, only IAT 6, 5, 4 and 3.5 will be used because as Figure 17 shows, the number of seats that the manufacturing can produce declines after an IAT of 3.5.

According to the current state analysis' resource utilisation and process waiting times, some of the resources were moved. From the future state, a new process flow diagram will be created to show these resource re-allocations and new process times.

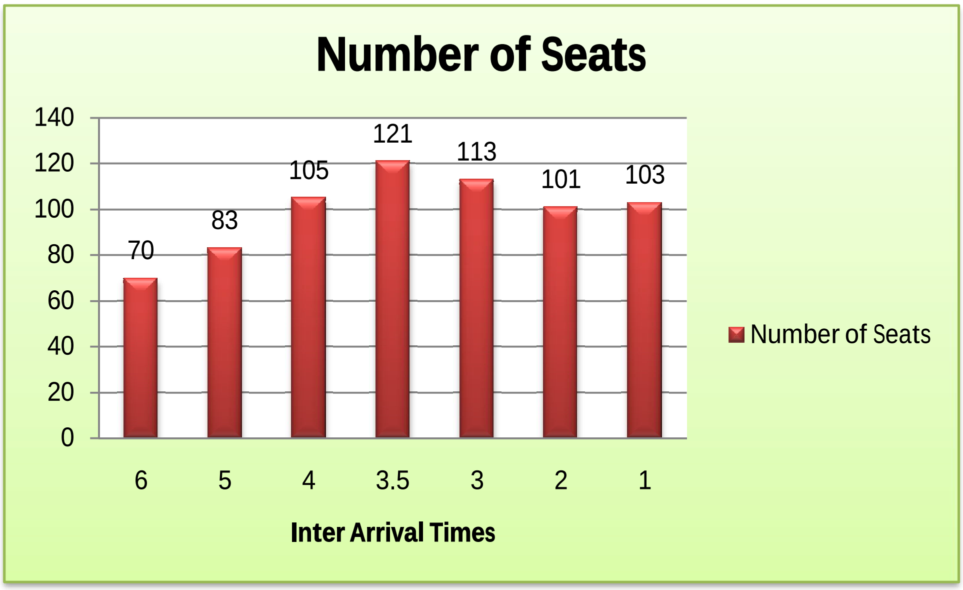


Figure 17: Finished seats for IAT (future state)

The future state analysis shows that, with the improvements made, 121 seats can be manufactured in 60 days. Although some resources are utilised 80% of the time and others only 50% of the time, compared to the original utilisation from the current state analysis, the future state resource utilisation (Figure 18) is much more even and the average utilisation is higher. These process times and workers that have been reallocated can be seen in Figure 22.

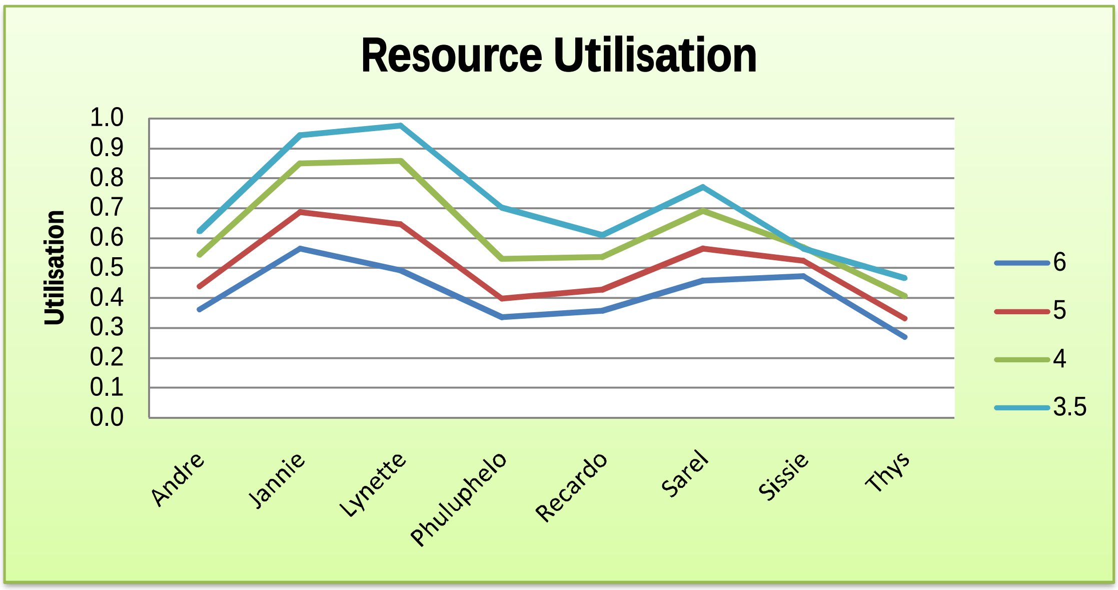


Figure 18: Future state resource utilisation

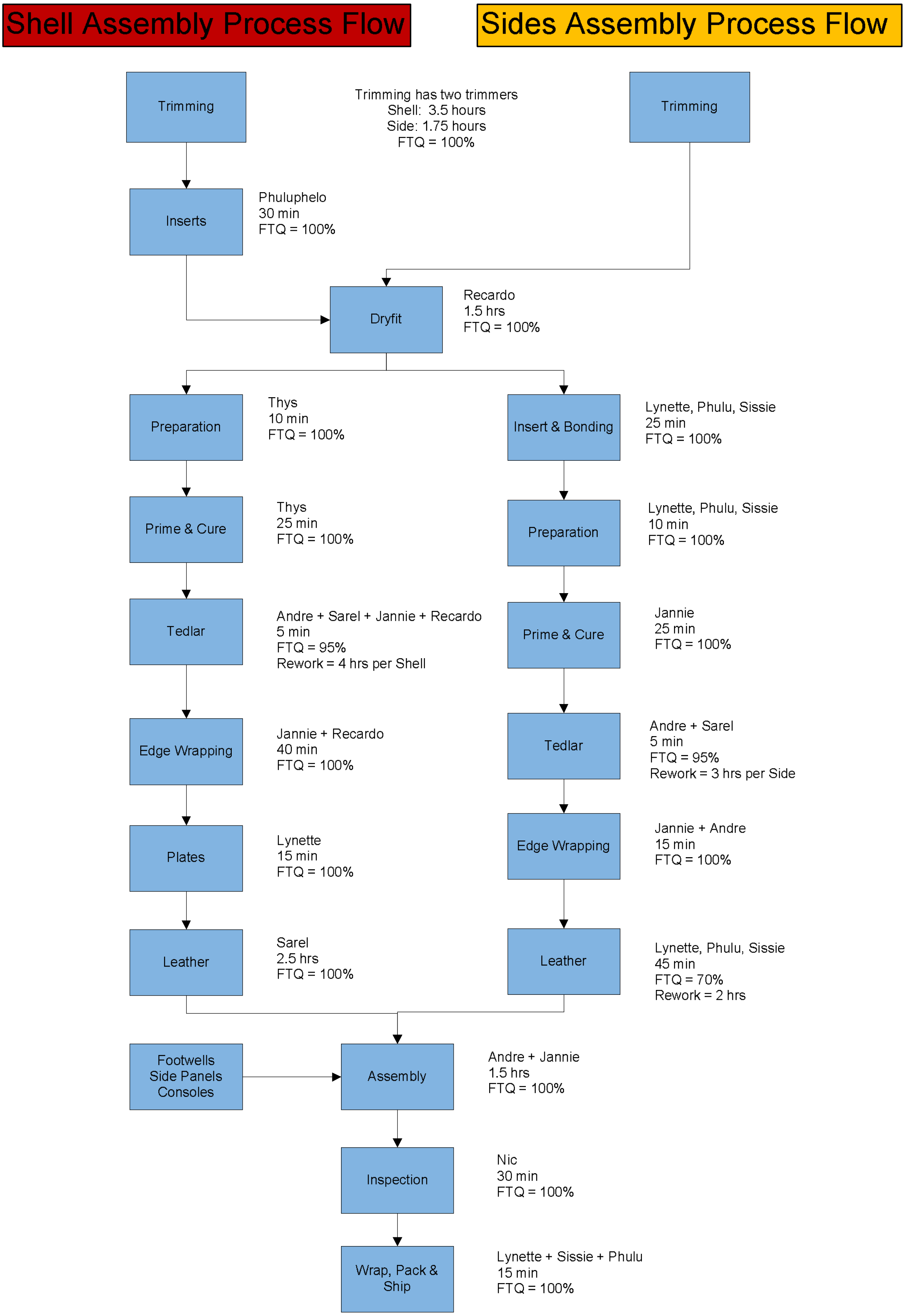


Figure 19: Shell & side process flow (future state)

Figure 20 shows the resources' process times which indicates a big improvement from the current state as can be seen in appendix B4.

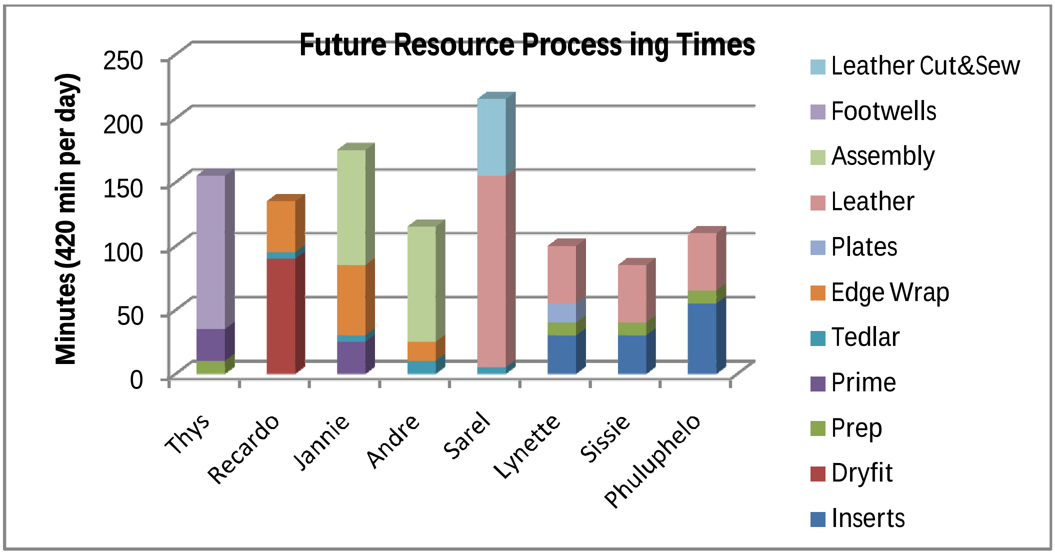


Figure 20: Future resource processing times

From Appendix D3, the process waiting times show that the side leather queue has the longest waiting time. In Figure 20 the pink parts are the leather process times and the graph in Appendix D3 combines these times to show the total leather process times. The resource utilisation, process waiting times and process cycle times suggests that Leather will be the biggest constraint in the Assembly Cell which is why there will be a buffer at Leather in the value stream map.

Value Stream Mapping

Figure 21 shows the new future state value stream map. As previously motivated, there will be a buffer for parts that are waiting to be processed at Leather and close communication will be kept between the buffer and production control and production control and Lay-up, which is the drum of the manufacturing line.

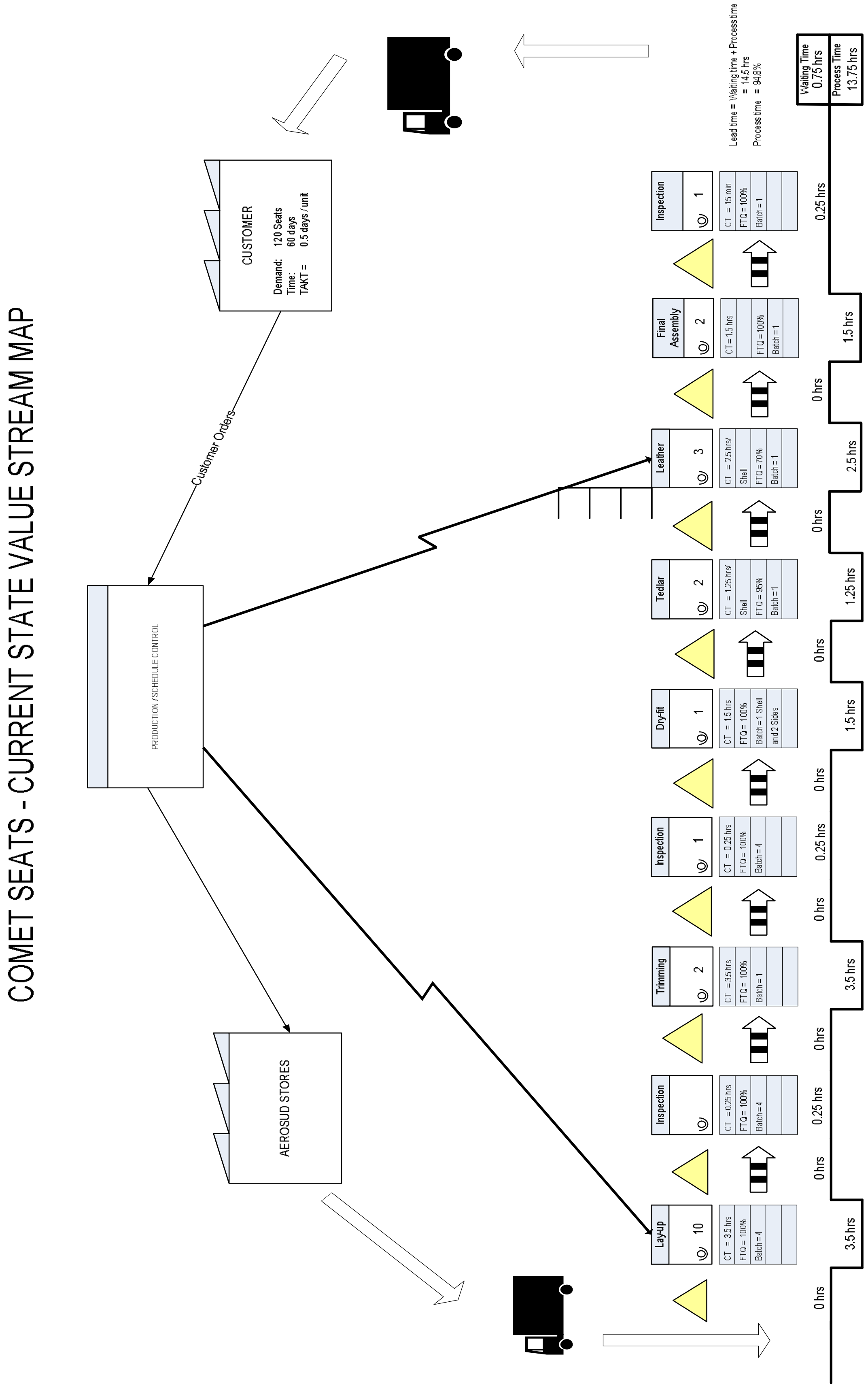


Figure 21: Future state VSM

4.3 Final Proposal

The goal of the future state analysis has been to find an achievable future state to cope if Aerosud chooses to accept more projects. The proposal is based on the analysis of the simulation model with the improvements in place. Without these improvements the proposal is void and only a demand increase of up to 88 seats in 60 days is achievable.

With the improvements in place, the future state analysis supports a demand increase of up to 121 seats in 60 days. Figure 19 shows the resource or worker allocation and process times for the future state.

Throughput, Inventory & Operating Expenses

For any change to be successful, at least one of these three measures needs to be improved. *Throughput* means decreasing the lead time and producing more seats more quickly, but if the demand stays the same there is no reason to increase production. If Aerosud want to increase demand they need to accept more projects, this is why it is very important to know the production line's potential because operating at a higher production rate will increase the return on investment. This report has shown that the current state can handle just over seven seats per week and the future state 12 seats per week. According to the future state VSM the takt time is 0.5 days per part, comparing the old takt time with the new takt time, this is an improvement of more than a seat per day.

The main object for Aerosud firstly will be to create a pull system to decrease the *inventory* in the system. This will decrease the lead time and free up some cash.

Man-hours are responsible for 70% of the *operating expenses* and the current state analysis have shown that almost 1300 hours can be saved and the future state (if the takt time is taken into consideration) will be able to produce 48 seats in 24 days. That is a total of 36 days saved.

Conclusion

This project shows that the current state can, at the very least, decrease inventory and at the very most, decrease operating expenses and increase throughput. This illustrates that that with the cooperation of management and the shop floor, the seats manufacturing line has the potential to handle an increase in demand and create a higher return on investment for the company.

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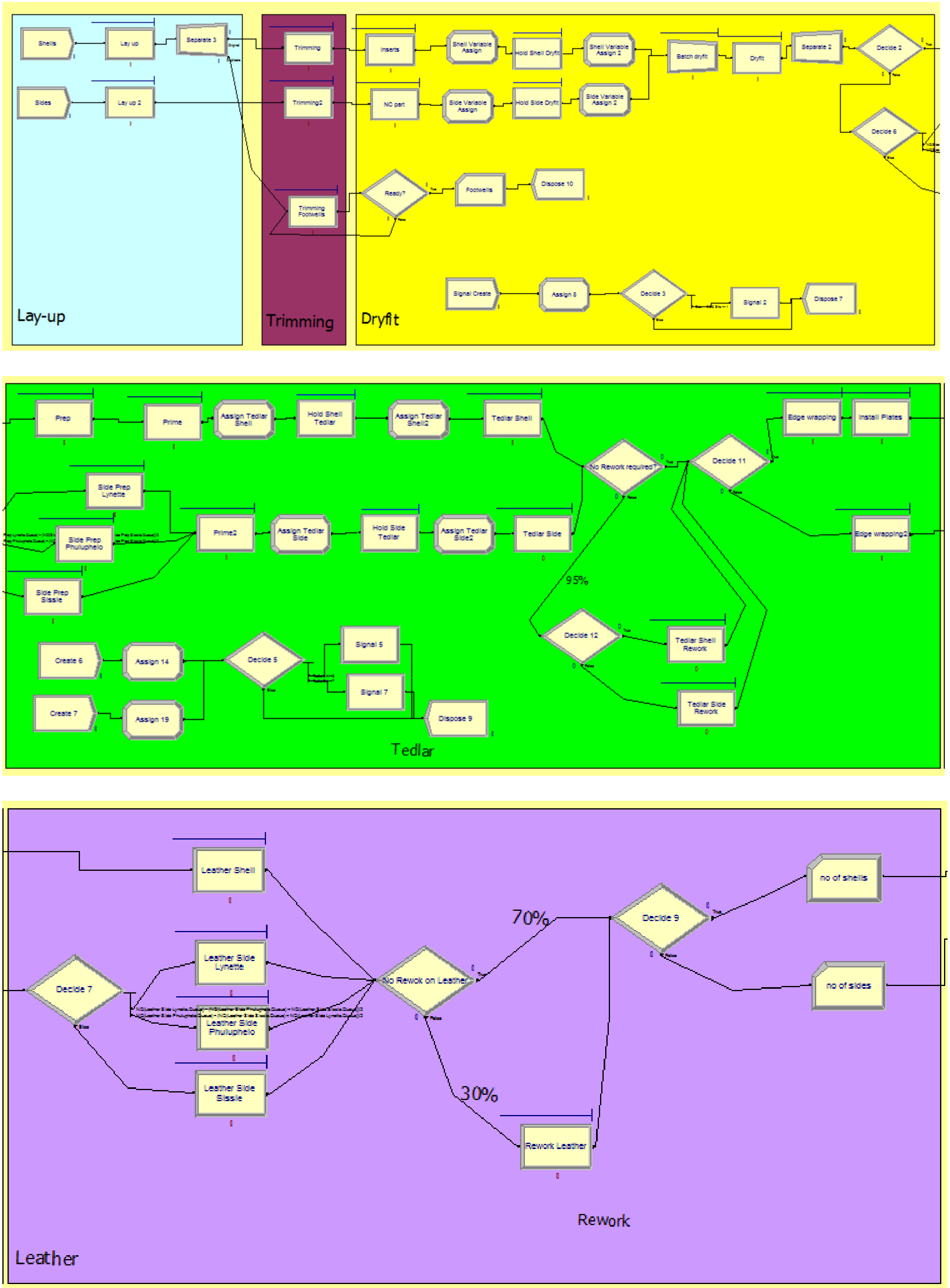
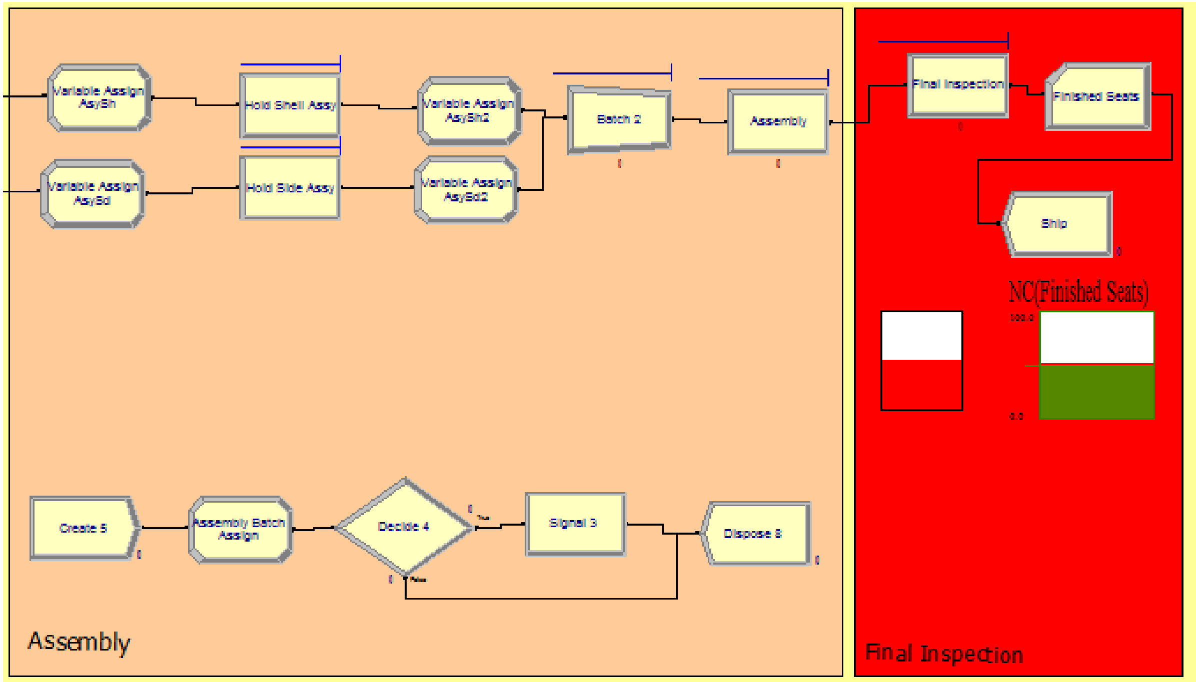
www.tsitsamis.gr/?Container_Terminals:SIMULAT

Appendices

Appendix A: Simulation Model Picture Overview





Variable Assign AsySh
Hold Shell Assy
Variable Assign AsySh2
Batch 2
Assembly
Variable Assign AsySd
Hold Side Assy
Variable Assign AsySd2
Final Inspection
Finished Seats
Ship
NC(Finished Seats)
Create 5
Assembly Batch Assign
Decide 4
Signal 3
Dispose 8
Assembly
Final Inspection

Appendix B: Arena Output (Current State)

Appendix B1

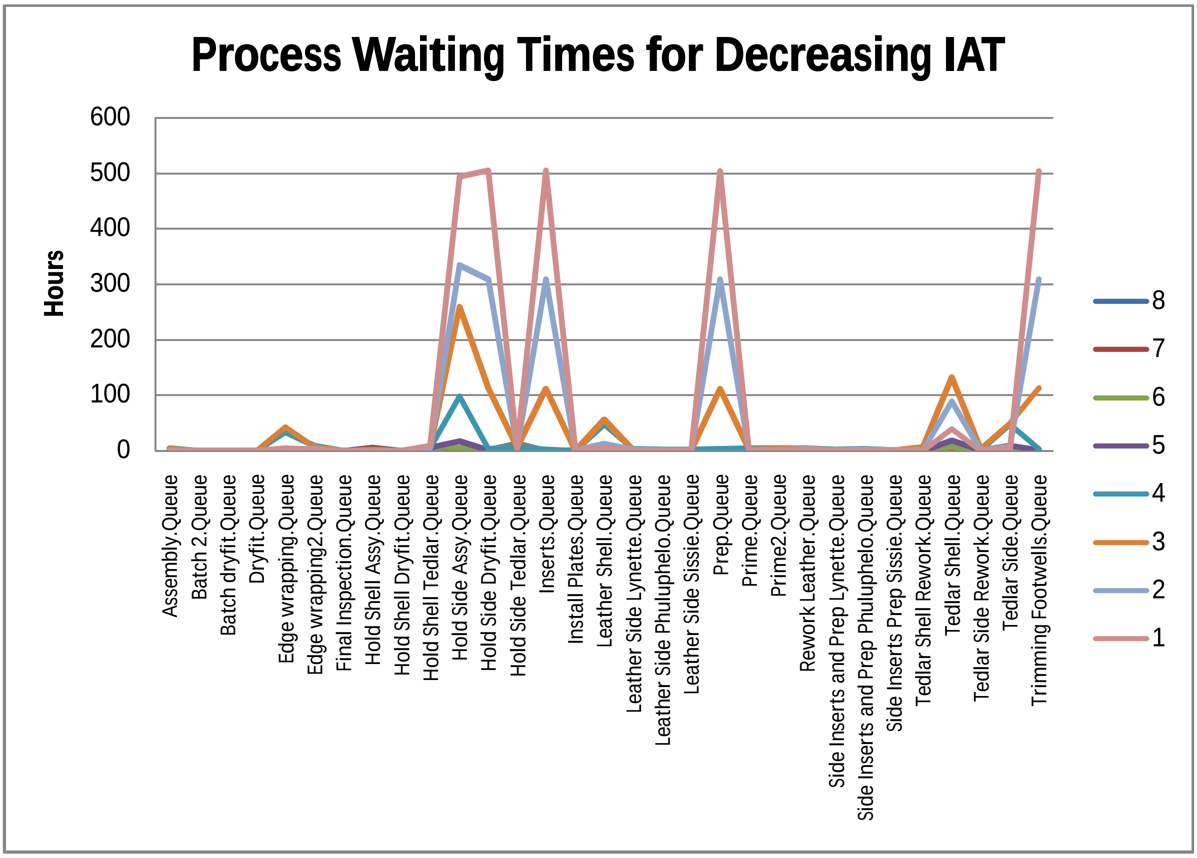
Arena Current State Output

	Waiting Time							
Assembly.Queue	0.56	0.40	0.37	0.78	5.12	3.47	1.38	0.59
Batch 2.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batch dryfit.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dryfit.Queue	0.05	0.14	0.06	0.18	0.42	0.18	0.38	0.55
Edge wrapping.Queue	0.57	0.61	0.59	2.36	33.22	42.10	3.53	4.40
Edge wrapping2.Queue	0.85	0.99	1.26	2.94	8.76	6.57	3.42	2.25
Final Inspection.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hold Shell Assy.Queue	5.79	4.96	2.34	0.47	0.53	0.02	0.02	0.02
Hold Shell Dryfit.Queue	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02
Hold Shell Tedlar.Queue	8.15	7.80	6.19	5.98	4.85	5.12	6.12	9.05
Hold Side Assy.Queue	3.91	3.31	5.47	17.36	97.42	259.16	334.80	493.61
Hold Side Dryfit.Queue	0.59	0.63	0.74	0.98	2.87	112.82	309.66	505.27
Hold Side Tedlar.Queue	12.22	11.17	9.40	8.01	6.87	5.43	5.34	5.09
Inserts.Queue	0.05	0.10	0.21	0.44	2.34	112.29	309.13	504.74
Install Plates.Queue	0.01	0.06	0.48	0.77	0.38	0.40	0.99	0.93
Leather Shell.Queue	1.60	1.94	2.95	7.86	47.42	56.11	12.95	6.34
Leather Side Lynette.Queue	0.65	0.96	0.65	0.74	3.25	1.29	2.00	1.04
Leather Side Phuluphelo.Queue	0.32	0.30	0.31	0.43	2.03	1.17	1.02	0.48
Leather Side Sissie.Queue	0.49	0.54	0.53	0.68	2.47	1.48	1.52	1.07
Prep.Queue	0.41	0.27	0.45	0.67	3.12	111.92	309.24	504.25
Prime.Queue	0.27	0.42	0.73	0.96	4.74	2.83	1.37	0.89
Prime2.Queue	0.44	0.48	0.72	1.15	4.81	2.90	0.96	0.66
Rework Leather.Queue	1.36	1.71	2.01	2.82	4.41	4.27	3.22	2.31
Side Inserts and Prep Lynette.Queue	0.00	0.50	0.60	1.02	1.99	0.89	1.45	0.85
Side Inserts and Prep Phuluphelo.Queue	0.00	0.00	0.00	0.00	3.36	1.90	2.63	0.51
Side Inserts Prep Sissie.Queue	0.54	0.55	0.57	0.61	0.73	0.68	0.70	0.65
Tedlar Shell Rework.Queue	0.08	0.00	0.04	0.41	1.69	6.81	1.25	0.34
Tedlar Shell.Queue	1.21	1.51	5.89	18.47	88.79	132.85	88.89	39.19
Tedlar Side Rework.Queue	0.00	0.43	0.50	0.78	0.97	3.07	1.20	0.10
Tedlar Side.Queue	1.72	1.56	3.78	9.06	47.42	49.95	7.56	5.01
Trimming Footwells.Queue	0.52	0.52	0.65	0.86	2.96	112.76	309.86	504.36
IAT	8	7	6	5	4	3	2	1

Utilisation								
	IAT = 8	IAT = 7	IAT = 6	IAT = 5	IAT = 4	IAT = 3	IAT = 2	IAT = 1
Andre	0.28	0.32	0.37	0.43	0.47	0.46	0.37	0.36
Inspector	0.03	0.04	0.04	0.05	0.05	0.05	0.03	0.03
Jannie	0.48	0.56	0.64	0.77	0.87	0.83	0.72	0.70
Lynette	0.13	0.16	0.19	0.22	0.29	0.30	0.37	0.43
Phuluphelo	0.06	0.06	0.07	0.08	0.15	0.14	0.17	0.19
Recardo	0.39	0.46	0.53	0.63	0.78	0.83	0.86	0.93
Sarel	0.55	0.68	0.85	0.92	0.99	0.95	0.83	0.84
Sissie	0.36	0.41	0.45	0.53	0.62	0.68	0.76	0.80
Thys	0.50	0.52	0.63	0.76	0.95	1.00	1.00	1.00

Number of Seats Produced								
	IAT = 8	IAT = 7	IAT = 6	IAT = 5	IAT = 4	IAT = 3	IAT = 2	IAT = 1
Finished Seats	53	62	68	85	88	79	53	45

Appendix B2



Appendix B3

Report: (This report relates to the above Figure and Figure 17)

Hold Side Assy: This is a buffer where sides are waiting for the corresponding shells to arrive.

Reason: Resources further up in the production line are too busy.

Hold Side Dryfit: This is a buffer where sides are waiting for the corresponding shell.

Reason: There is a process just in front of Dryfit that spends about 30 minutes on a shell before it is dryfitted.

Inserts: This is the process in front of Dryfit.

Reason: Thys is very busy

Prep: The part is sanded a last time and prepared for tedlar. (The surface has to be extremely smooth and this takes time.)

Reason: Thys is very busy.

Tedlar Shell: There are four workers needed to Tedlar a shell.

Reason: Recardo, Jannie and Sarel are very busy.

Trimming Footwells: This is a long process, also done by Thys.

Reason: Thys is over utilised and because two of his tasks are at the beginning of the manufacturing line he is struggling to get everything done. Trimming of the footwells is also a very long process.

Edge Wrapping: Not a problem until the IAT gets below 5.

Reason: The two workers, Jannie en Recardo, have other tasks as well.

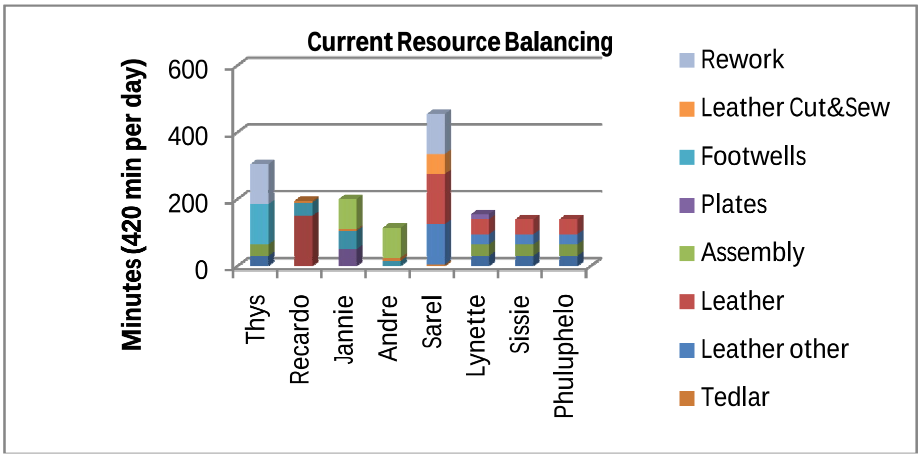
Leather Shell: From the data this process always has a long queue.

Reason: There is only one man doing the job at this stage and it is a very long processes.

Tedlar Shell: They have to wait till there are four Shells before they can Tedlar them.

Reason: Preceding processes become busy as the arrival rate get higher and this means that the workers also get very busy. (Especially Recardo and Jannie.)

Appendix B4


Current Resource Balancing
Minutes (420 min per day)
600
400
200
0
Thys
Recardo
Jannie
Andre
Sarel
Lynette
Sissie
Phuluphelo
Rework
Leather Cut&Sew
Footwells
Plates
Assembly
Leather
Leather other
Tedlar

Appendix C: General Improvements

Dryfit: On the Dryfit jig two sides and a shell are fitted together and then they are trimmed to fit each other perfectly. There are always gaps on specific places that the person doing the Dryfit needs to fill, which takes up almost an hour of the time. If Lay-up can fix this problem, an hour can be saved.

Prep: This is after Dryfit where a part is being sanded again, this is a waste of over processing. Especially because they have to wait for a spray booth, this means it is 35 minutes times 8 sides that they have to wait. If the Lay-up produces a better finish, the time spent on preparation will decrease.

Prime: When a part has been prepared, it is primed with glue, put in the oven to cure for a few minutes and then vacformed to apply the tedlar. The problem is that a spray booth is needed when the glue is applied and this spray booth is shared with other departments. This means that it has to be booked for a certain time, it is for this reason that they wait untill all 8 (if they have to ship 4) sides or 4 shells are ready. This disturbes the continuous flow. If an extra spray booth can be added to the cell, continuous flow can be achieved.

Edge Wrapping: After Tedlar, the excess tedlar is cut off and the edges folded in. A heat gun is required to help the tedlar which is folded in stick. More heat guns are required if more workers are applied here. The leather also requires a heat gun so if the processes are going to run simultaneously, they will need to aquire more heat guns.

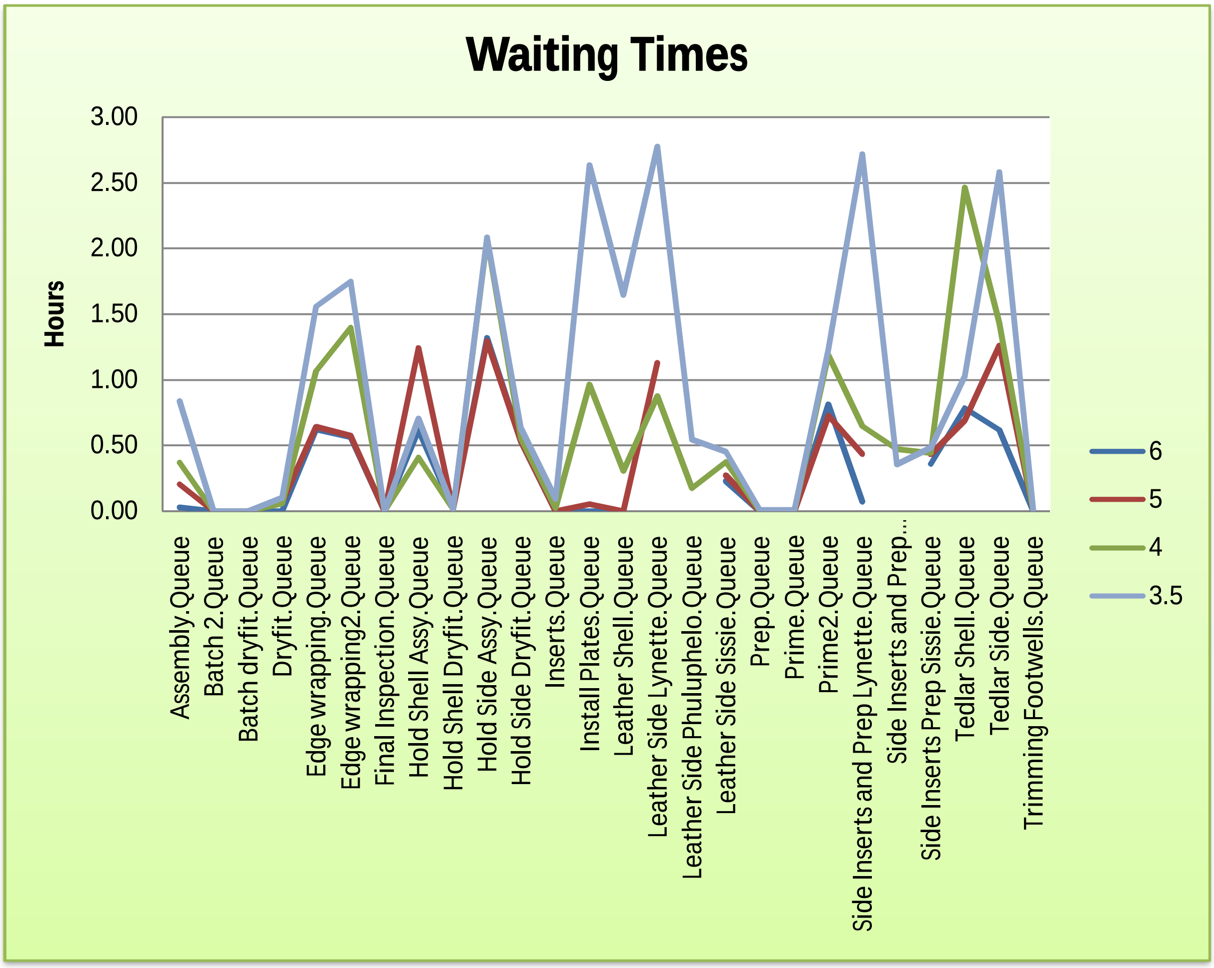
Rework on leather: The lighting at the Leather cell is not very good with the result that the person cutting and sewing the leather cannot see small holes or defects in the leather. These holes can then only be seen after the leather has been applied to a part and then the whole process has to be redone and an extra piece of leather has to cut as well. This occurs 30% of the time. Three to four hours can be saved if better lights are installed. Higher quality material will also solve this problem but will cost more.

Appendix D: Future State Output

Appendix D1: Arena Future State Analysis

Inter Arrival Times vs Waiting Times	6	5	4	3.5	3	2	1
Assembly.Queue	0.03	0.20	0.37	0.84	25.60	19.20	21.15
Batch 2.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batch dryfit.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dryfit.Queue	0.00	0.07	0.06	0.10	0.82	26.85	275.68
Edge wrapping.Queue	0.62	0.64	1.07	1.55	40.16	0.09	1.72
Edge wrapping2.Queue	0.57	0.57	1.40	1.74	27.75	58.51	23.38
Final Inspection.Queue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hold Shell Assy.Queue	0.62	1.25	0.41	0.71	0.02	0.00	0.02
Hold Shell Dryfit.Queue	0.02	0.02	0.02	0.02	0.02	0.01	0.02
Hold Side Assy.Queue	1.32	1.30	2.07	2.08	69.53	114.15	255.24
Hold Side Dryfit.Queue	0.53	0.53	0.56	0.63	1.36	52.81	271.92
Inserts.Queue	0.00	0.00	0.03	0.09	0.83	26.16	271.96
Install Plates.Queue	0.00	0.05	0.97	2.63	13.19	2.54	20.64
Leather Shell.Queue	0.00	0.00	0.31	1.65	17.14	3.76	24.40
Leather Side Lynette.Queue		1.13	0.88	2.77	8.77	2.86	25.83
Leather Side Phuluphelo.Queue			0.17	0.55	1.61	4.30	266.47
Leather Side Sissie.Queue	0.23	0.27	0.38	0.45	0.75	1.33	4.93
Prep.Queue	0.00	0.00	0.00	0.01	0.12	0.16	140.62
Prime.Queue	0.00	0.00	0.00	0.01	0.05	0.05	139.88
Prime2.Queue	0.81	0.73	1.19	1.23	25.32	62.53	21.47
Side Inserts and Prep Lynette.Queue	0.07	0.43	0.65	2.72	7.29	2.09	25.05
Side Inserts and Prep Phuluphelo.Queue			0.47	0.36	1.01	2.54	269.07
Side Inserts Prep Sissie.Queue	0.36	0.43	0.44	0.48	0.45	1.30	3.47
Tedlar Shell.Queue	0.78	0.69	2.46	1.03	49.20	119.75	48.88
Tedlar Side.Queue	0.62	1.26	1.43	2.58	4.50	3.69	5.29
Trimming Footwells.Queue	0.00	0.00	0.00	0.00	0.05	0.03	139.78
	6	5	4	3.5	3	2	1
Andre	0.36	0.44	0.54	0.62	0.61	0.60	0.60
Jannie	0.56	0.69	0.85	0.94	1.00	1.00	1.00
Lynette	0.49	0.65	0.86	0.98	0.94	1.00	1.00
Phuluphelo	0.34	0.40	0.53	0.70	0.90	1.00	1.00
Recardo	0.36	0.43	0.54	0.61	0.71	0.83	0.81
Sarel	0.46	0.57	0.69	0.77	0.80	0.75	0.72
Sissie	0.47	0.52	0.57	0.57	0.59	0.82	0.87
Thys	0.27	0.33	0.41	0.47	0.52	0.77	1.00
	6	5	4	3.5	3	2	1
Number of Seats	70	83	105	121	113	101	103

Appendix D2



Appendix D3