Schedule Delays and Quality Assurance: ShelvCraft
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Executive Summary

Every company has constraints/limitations that prevent it from reaching its ultimate objective/goal which is the net profit. Requirements needed to be fulfilled in order to reach this ultimate goal is to increase throughput, decrease operating expenses and keep “work-in-process” inventory at the most economical level. These are but direct factors that contribute to a successful company; however, factors such as poor quality, employee morale and motivation, employee health and safety etc. are all indirect limitations or constraints to a successful company.

The most critical task in eliminating a constraint is identifying the constraint. Once the identification process is completed, trade off analysis can be undertaken to adopt the most feasible alternative.

ShelvCraft, like any other company had limitations to attaining its optimal net profit, which included schedule delays, as well as poor quality. Poor quality is a critical factor that contributes to a bad company reputation which is an emphasized concept in unsuccessful companies.

These constraints were identified and proposed solutions were given using theory, tools and techniques from “Theory of Constraints”, “Lean Manufacturing”, as well as “Process Capability and Control Charts”
Contents

1 Chapter 1: Introduction ........................................................................................................5
  1.1 Background ..................................................................................................................5
    1.1.1 Company Profile ...............................................................................................5
    1.1.2 History ..............................................................................................................5
    1.1.3 General ................................................................................................................5
  1.2 Problem Statement ........................................................................................................8
  1.3 Research Objectives ......................................................................................................9
  1.4 Scope ..........................................................................................................................10
  1.5 Literature Review ........................................................................................................11
    1.5.1 General .............................................................................................................11
    1.5.2 Theory of Constraints ......................................................................................11
    1.5.3 Lean Manufacturing .........................................................................................12
    1.5.4 Quality Management ......................................................................................13
  1.6 Overview of Chapters ...................................................................................................15

2 Chapter 2: Applied Literature Review ..............................................................................16
  2.1 Literature Review Part 2: In depth literature review on chosen techniques and
    methodologies .............................................................................................................16
    2.1.1 Theory of Constraints ......................................................................................16
    2.1.2 Process Capability and Control Charts ............................................................18
  2.2 Chosen Techniques ......................................................................................................22

3 Chapter 3: Methodology ....................................................................................................23
  3.1 Model Presentation ......................................................................................................23
    3.1.1 Control Charts and Process Capability .............................................................23
    3.1.2 Constraint Elimination for Improved Throughput ............................................23
  3.2 Model Implementation and Analysis ..........................................................................24
    3.2.1 Elimination of Schedule Delays ......................................................................24
    3.2.2 Quality Control ..............................................................................................27
1 Chapter 1: Introduction

1.1 Background

1.1.1 Company Profile

✓ Vision:

  o To be the best at what we do.

  o To broaden our Supply Chain and Distribution Channels Nationally and Internationally.

✓ Mission:

  o Retaining our customers through continuous enhancements in product solutions and services, and growing our customer base.

✓ Executives:

  o Anver Essa – Chairman and MD.

  o Mohammed Essa – Marketing and Sales.

  o Galib Essa - Special Projects

A more descriptive profile of the company can be found in the Appendix

(Appendix Section 4.4. Company Catalogue)

1.1.2 History

ShelvCraft has previously had consultants come in to improve their efficiency with regards to quality, productivity and customer services by looking at various factors:

✓ The entire factory layout was changed by separating scrap from conforming products and in essence providing waste dumps to throw scrap away so as to make it easier and quicker to identify inventory to be transferred to the next processing station.

✓ Space was provided to pile work in progress inventory.

✓ Stoppers were placed in bending machinery as to provide quick and efficient methods of determining where to bend the steel sheets rather than manual measurements.

✓ Inspectors qualified in quality management were hired to do inspections as to identify defective items or defects in items.

1.1.3 General
ShelvCraft is recognized as an industry leader in Shelving, Racking and Display solutions that was founded over 26 years ago by Anver Essa. It has gradually developed into what is now known as a tier one manufacturer.

ShelvCraft’s steel manufacturing plant is situated in Sunderland Ridge. They have their retail outlets located in Pretoria West and Polokwane.

ShelvCraft produces a variety of products ranging from a variety of materials. The focus of this report, however, is based on the steel manufacturing plant.

Some of steel produced items at this plant are:

- **Wire Smart Racking**
  - Stackable Basket Sets
  - Large Stackables
  - Gondola 1524 High 457 Base
  - Wire Smart Shelve Unit
  - Flea Market Basket
  - Magazine Stand Wire Smart
  - Square Dump Bin
  - Round Dump Bin etc.

- **Medium and Heavy Duty Racking**
  - Scaffolding
  - Cantilever Racking

- **Shelving**
  - Bolt & Nut Shelving
  - Boltless Pre Packed Shelving
  - Rivet Shelving
  - Wall Shelving
  - Gondola Shelving

- **Display Solutions**
  - Linbin Displays

The processes involved in the production of these items vary from the following:
• Cutting
• Bending
• Punching
• Welding
• Galvanising
• Trimming
• Washing
• Powder Coating etc.

A Demand List of the products mentioned can be found in the Appendix.

(Appendix Section 4.1. Table 1)

The Factory Plan and Layout can also be found in the Appendix.

(Appendix Section 4.4. Company Catalogue)
1.2 Problem Statement

The daily demand for the “Bolt & Nut Shelving” and the “Stackable Basket Sets” is 150 units and 180 units respectively.\textsuperscript{1} ShelvCraft however, is only producing 100 units and 150 units per day respectively on average. These products are thus behind schedule. The possible constraints limiting this production rate can either be:

- The misusing of processes/machine capacity.
- Incapacitated machines/other resources and thus the possible existence of a bottleneck.

The evidence of the existence of a bottleneck would generally be found in a pile up of work-in-process inventory awaiting a constrained resource. This concept was validated in the pile up viewed at both the washing and powder coating machines.

The description of both the washing and powder coating processes can be found in the Appendix.

\textit{(Appendix Section 4.2. The Production Process)}

ShelvCraft has received increased customer complaints on the standard of measurements as well as quality issues regarding deformities on products. ShelvCraft inspectors have also informed Management of the growing number in completely defective or deformed products especially in the Wire Smart Racking Products mentioned in the Introduction above.

ShelvCraft has also requested a general improvement to the plant and a desire to improve production rates.

Process Flow Charts of the two mentioned constrained products showing the Bill of Routes for these products can be viewed in the Appendix.

\textit{(Appendix Section 4.3. Figure 1 & 2)}

A Bill of Routes was obtained for all products that influence the routes taken for these two products in order to obtain available times and allocated times of machines to each product, to enable identification of a bottleneck. Data relating to the shared resources can be found on Table 3 in the Appendix.

\textit{(Appendix. Section 4.1. Table 3)}

\textsuperscript{1} Appendix Section 4.1. Table 1
1.3 Research Objectives

Research will be conducted in a structural format taking into consideration what has already been improved over the past few years at ShelvCraft and whether any of these improvements are still contributing in a positive manner to the overall plant performance.

Surveys and Interviews were conducted with various employees as well as Management in order to obtain a better idea of why ShelvCraft has the above mentioned problems.

All data required as well as assurance of the availability of data to be obtained was ensured.

Various Journals, textbooks and the internet will be used to obtain theoretical information as well as applied techniques used in the past to solve similar problems experienced in similar fields.
1.4 Scope

The focus of this report will tackle the most important limitations experienced by ShelvCraft first and then move to the rest in hope that this will eventually give ShelvCraft its general plant improvement.

A literature review will be conducted theoretically first and then be moved to an applied level focussing on concepts and techniques used in the past to address similar problems in similar fields. Some of the literature review conducted will be based on:

- Bottleneck identification theory and techniques.
- Quality and standard related topics
- Productivity
- Synchronous and Asynchronous Manufacturing
- Process Capability etc.

A more in depth literature review will then be conducted in Chapter 2, using the chosen theory and techniques.

Once sufficient literature and knowledge of the problems at hand are obtained, the problems will be analysed, models used will be presented, implemented and a recommendation will then be offered.
1.5 Literature Review

1.5.1 General

1.5.1.1 What is a bottleneck?

✓ A bottleneck is a delay caused when one part of a process or activity is slower than the others and so hinders overall progress. *(Encarta Dictionary)*

✓ A bottleneck is defined as any resource whose capacity is less than the demand placed upon it. *(Chase et al. 2006)*

1.5.1.2 The link between Quality and Productivity

Producing high quality products in the modern industrial environment is not easy. A significant aspect of the problem is the rapid evolution of technology. When technological advances occur rapidly and when the new technologies used quickly to exploit competitive advantages, the problems of designing and manufacturing products of superior quality are generally complicated. Often too little attention is paid to achieving all dimensions of an optimal process: economy, efficiency, productivity and quality. Effective quality improvement can be instrumental in increasing productivity and reducing cost. *(Montgomery, 2009)*

1.5.2 Theory of Constraints

Theory of Constraints is a multifaceted philosophy which emerged in the early 1980’s. The development of TOC is credited in the main to Dr. Eliyahu Goldratt, an Israeli physicist who has had a remarkable impact on the business world, especially in the U.S. Goldratt’s revolutionary method for production scheduling was in stark contrast to accepted methods available at the time, such as Material’s Requirements Planning (MRP). TOC is more than a set of tools or techniques, though it certainly does contain those. It is more fundamentally a paradigm shift which demands that we think about our problem, our goals and objectives, policies, procedures and measures in a different way.

TOC promotes the use of global systemised measures rather than local measures. The motivation for this is that if a system as a whole is to achieve its goal, it is best for the system’s individual parts to work as a team in “sync” rather than at own individual speeds.

The TOC thinking process is a suite of tools that allows people to learn and use the Thinking Process that enable them to develop their own solutions to complex problems and to implement them successfully. This suite of tools enables analysis of a situation, using the right of cause and effect thinking following strict logic rules combined with intuition and knowledge of the persons intimately involved with the problem. The Thinking Process enables more complex problems to be tackled and have much in common with other soft systems approaches, such as Soft Systems Methodology and Strategic Options Development.

The TOC process is neither a panacea nor a recipe, but it is a philosophy that helps lead success in a very real way.
A survey identified of around 400 items; including nearly 40 books, relating to TOC. Of these, only a handful contained negative comments, and none of these related to actual applications of the methodology.

(Victoria J. Mabin et al. 2000)

TOC views organizations as systems consisting of resources, which are linked by the processes they perform. The goal of the organization serves as the primary judge of success. Within that system, a constraint is defined as anything that limits the system from achieving higher performance relative to its purpose. The pervasiveness of interdependencies within the organization makes the analogy of a chain, or network of chains, very descriptive of a system’s processes. Just as the strength of a chain is governed by its single weakest link, the TOC perspective is that the ability of any organization to achieve its goal is governed by a single, or at most very few, constraints. While the concept of constraints limiting system performance is simple, it is far from simplistic. To a large degree, the constraint/non-constraint distinction is almost totally ignored by most managerial techniques and practices. Ignoring this distinction inevitably leads to mistakes in the decision process. The implications of viewing organizations from the perspective of constraints and non-constraints are significant. Most organizations simultaneously have limited resources and many things that need to be accomplished. If, due to misplaced focus, the constraint is not positively affected by an action, then it is highly unlikely that real progress will be made toward the goal. Given this perspective, TOC’s 5-step process offers a systematic and focused process which organizations use to successfully pursue ongoing improvement:

The Five Focusing Steps
  1) Identify the system’s constraint.
  2) Decide how to exploit the system’s constraint.
  3) Subordinate everything else to the above decisions.
  4) Elevate the system’s constraint.
  5) Don’t allow inertia to become the system’s constraint. When a constraint is broken, go back to step one.

However, prior to identifying the constraint, two prerequisites must be satisfied to gain perspective for the analysis.

  1) Define the system and its purpose (goal).
  2) Determine how to measure the system’s purpose.

1.5.3 Lean Manufacturing

The Lean enterprise is focused on the elimination of muda—waste. Drawing on a rich history of Japanese manufacturing techniques, Lean advocates also outline a five-step process. Based on a customer-focused systems view, this process provides the foundation of any lean enterprise.

  1) Specify Value
  2) Identify the Value Stream
  3) Flow
  4) Pull
  5) Perfection
A waste-free process is a process that is working correctly. It takes time and effort to get the waste out of a process, so it is important to work on processes that create value. A firm’s customers are the final judges as to whether or not the firm has created value. Therefore, one category of muda (waste) is having the “right” process for a product or service that the customer doesn’t want. Lean companies therefore work to precisely define value in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customers. In other words, they work to understand and deliver what the customer wants to buy. Lean companies often restructure on the basis of product line, organizing managers and employees into product teams.

Moore and Scheinkopf, 1998

1.5.4 Quality Management

1.5.4.1 General

Garvin (1987) provides an excellent discussion of eight components or dimensions of quality. Summarizations of his key points concerning these dimensions of quality are as follows:

1. Performance: Ensuring that the product will do the intended job. Potential customers usually evaluate a product to determine if it will perform certain specific functions and determine how well it performs them.

2. Reliability: Ensure reliability in reducing failure frequencies and prevent failures. (Long term usage?)

3. Durability: Ensure that the product has the required life time usage.

4. Serviceability: Ensure ease of repairing exists.

5. Aesthetics: Visual appeal of the product. (Packaging Alternatives?)

6. Features

7. Perceived Quality: What is the reputation of the company or its product? In many cases, customers rely on past reputation of the company concerning quality of its product. Ensure positive reputation by ensuring good quality. Reputation is directly influenced by failures of the product that are highly visible to the public or that require product recalls.

8. Conformance to Standards: Ensure user-requirements fulfilment. High quality is directly related to exact fulfilment of user specifications.

Quality is the fitness for use of a product. It is inversely proportional to variability and thus an improvement in quality is the reduction of variability in processes and products.

Montgomery, 2009

Quality is an emerging concept. In the past, quality meant “conformance to valid customer requirements”- that is, as long as an output fell within acceptable limits, called specification limits, around a desired value, called a nominal value; it was deemed conforming, good or acceptable. This is referred to as the Goalpost Definition of Quality.
As the definition of quality has emerged, its meaning has shifted. A more current definition of quality states that: “Quality is a predictable degree of uniformity and dependability at low cost and suited to the market.”

(Gitlow et al. 2005)

1.5.4.2 Process Capability and Control Charts

Statistical process control (SPC) is a widely used process monitoring technique, especially in discrete process industries, for the continuous improvement of products and processes. SPC in the form of control charts (e.g., Shewhart charts and CUSUM charts) is useful in improving product quality by continually checking the “stable-state” system. When there is a departure from the stable-state of statistical control (due to certain special events) and detected by the control chart, the engineers or analyst then look for the assignable causes and try to eliminate them. While simulation models provide a “realistic” platform for better understanding of the new or redesigned system operation, the product and process quality dimensions of the manufacturing system are often overlooked.

(Nembhard et al. 1999)

From the perspective of simulation model design and analysis of manufacturing systems, there are potential benefits to integrate SPC techniques (in the form of control charts). With the graphical and object-oriented capabilities in current simulation software packages, integrating simulation models with on-line control charts can provide a great visualization aid for teaching and training shop-floor personnel the importance of each process step and the functionality and use of control charts. Parallel to the simulation modeling objectives, analysts can also experiment with the use of control charts at various process steps and play out many scenarios for idea generation, discussion, and eliminate any unforeseen obstacles and problems. Such knowledge and information would lead to more efficient implementation of SPC, which in turn would improve the manufacturing operations.

(Nembhard et al. 1999)

An external Excel program is used to construct and plot the necessary control charts, in this case X and MR chart. To automate and control the mechanical charting task, Visual Basic for Applications (see, e.g., Webb 1996) is used. We have successfully written the Visual Basic code necessary for the construction of X and MR chart and the interfacing with the ProModel program. A screen capture of the charts in action is shown in Figure 7. The figure shows the X and MR chart and their control limits which were calculated using Barrel 231 data prior to the simulation run. The dashed vertical lines signify the start of the simulation run where CT numbers are plotted for each batch. Using the XSUB function provided in the ProModel software, we have successfully interfaced the model simulation with the control charting. Figure 8 shows a screen capture of the program interface.

(Nembhard et al. 1999)
1.6 Overview of Chapters

Chapter 1 focussed on the Introduction of this report. An introduction to the company was given as well as their past improvements and current problems. A brief description of their problems was given with a literature study on possible techniques that can be used to tackle these issues.

Chapter 2 will focus on an in depth literature study on the chosen techniques as well as reasoning for this choice.

Chapter 3 will present the technique that will be used and it will explain how these techniques will be used to specifically relate to ShelvCraft’s problems. A recommendation will then be offered to ensure continuous improvement or maintenance of the implemented solutions.
Chapter 2: Applied Literature Review

2.1 Literature Review Part 2: In depth literature review on chosen techniques and methodologies.

2.1.1 Theory of Constraints

Central to the TOC philosophy is that any organisation has a constraint (or small number of constraints) which dominate the entire system. The secret to success lies with managing these constraints, and the system as it interacts with these constraints, to get the best out of the whole system.

Theory of Constraints or TOC can be applied in almost every field. The aim is to achieve the TOC thinking process which focuses on three major issues:

- What to change?
- What to change to?
- How to accomplish the change?

Ultimately, a change is required in an operation. That change will cause us to experience a benefit, a gain, an improvement; whether it is a decrease in inventory levels, an increase in throughput rate or a decrease in operational expenses. It is of course important to remember that increasing productivity is not necessarily a benefit, if an increase in productivity is not required, then increasing it may in actual fact increase operational expenses. For example, this might increase storage or carrying costs. If change in an operation cannot bring about a benefit, then does it reduce or eliminate a limitation? If neither of these is complied with, the process should possibly not be changed.

Theory of Constraints is used to identify bottlenecks and furthermore try to eliminate them by balancing flow rather than implementing local optimizations. Theory of Constraints will be used in conjunction with production scheduling.

Goldratt’s Rules of Production Scheduling:

1) Do not balance capacity, balance the flow.
2) The level of utilization of a non-bottleneck 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 by the bottleneck is an hour lost for the entire system.
5) An hour saved at a non-bottleneck 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 time.
9) Priorities can be set only by examining the system’s constraints. Lead time is a derivative of the schedule

(Goldratt, 2004)

Goldratt’s Theory of Constraints as applied to a manufacturing system:
1) **Identify** the system’s constraint. For the manufacturer, the question to be answered here is “what is physically limiting our ability to generate more throughput?” The constraint will be located in one of three places:
   1) the market (not enough sales),
   2) in the vendors (not enough materials), or
   3) in an internal resource (not enough capacity of a resource or skill set).

   From a long-term perspective, an additional question must be answered—if not immediately, then as soon as the operation is under control by implementing the next two steps. That question is **where does our organization want its constraint to be?** From a strategic perspective, where should the constraint be?

2) Decide how to **exploit** the system’s constraint. When we accept that the rate of throughput is a function of the constraint, and then the question to be answered at this step is, “**What do we want the constraint to do**, in order that the rate of throughput generated by it is maximized (now and in the future)?” The following activities and processes are typically implemented in association with this step:

3) **Subordinate** everything else to the above decisions. Step one identifies the key resource determining the rate of throughput the organization can generate. In step two, decisions are made relative to how the organization intends to maximize that rate of throughput—how to make the most with that it has. In this step, the organization makes and implements the decisions to ensure that its own rules, behaviors and measures enable, rather than impede its ability to exploit the identified constraint. “Subordinate” is the step where the majority of behaviour change occurs. It is also in this step that we define “buffer” and “rope:”

4) **Elevate** the system’s constraint. The first three steps represent the TOC approach to maximizing the performance of the initial system. In the “elevate” step, the constraint itself is enlarged. If the constraint is capacity of an internal resource, more of that capacity is acquired (additional shifts, process improvements, setup reductions, purchasing equipment, outsourcing, hiring people, etc.). If the constraint is materials, new sources for material are acquired. If the constraint is in the market, then sales and marketing bring in more business. At some stage during the elevate step the constraint will move to another location in the system.

5) Don’t allow **inertia** to become the system’s constraint. When a constraint is broken, go back to step one. This step reminds us to make it an ongoing improvement process. It also reminds us that once the constraint is elevated, to ensure there is sufficient protective capacity surrounding it. And that as the constraint changes, so must the rules, policies, and behaviors of the people in the organization.

Before applying these 5 steps, one has to:

1) Define the system and its purpose (goal)
2) Determine how to measure the system’s purpose

When applied to a manufacturing system, these requirements can be described as:

1) Define the system and its purpose (goal)
Given that the roots of TOC are deeply embedded in manufacturing, often the system is initially defined as the manufacturing operation, or the plant. The purpose of the manufacturing operation is to enable the entire organization to achieve its goal. It is important to have clear definition of the organization’s goal. One goal shared by most manufacturing companies is to make ‘make more money now as well as in the future.’ While this goal may be arguable in special circumstances, making money certainly provides the funds to fuel ongoing operations and growth regardless of other stated goals. As such, making money is at least a very tight necessary condition in almost every organization. As a result, it is appropriate to continue this example using ‘making more money now as well as in the future’ as the goal of the manufacturing organization. The next question to be answered is how do we measure ‘making money?’

2) Determine how to measure the system’s purpose.
Manufacturing organizations purchase materials from vendors, and add value by transforming those materials into products their customers purchase. Simply stated, companies are ‘making money’ when they are creating value added at a rate faster than they are spending.

(Moore and Scheinkopf, 1998)

2.1.2 Process Capability and Control Charts

A process is a set of inputs and outputs. There are uncontrollable inputs such as environmental factors or properties of raw materials provided by the external supplier and controllable inputs such as process variables i.e. temperature, pressure, feed rates and other process variables.

The production process transforms inputs into outputs (finished product) that have several quality characteristics.

Quality can go wrong in any stage in the route. The output variable is a quality characteristic that is a measure of the process and product quality.

A control chart is one of the primary techniques of statistical process control (SPC). A control chart plots the averages of measurements of a quality characteristic in samples taken from the process vs. Time (or the sample number). The chart has a CENTER LINE, an UPPER CONTROL LIMIT and a LOWER CONTROL LIMIT. The center represents where the process characteristic should fall if there are no unusual sources of variability present (ideal and unrealistic).

(Montgomery, 2009)

Control charts are used to identify and differentiate between common cause and special cause variation.

Control Charts are statistical tools used to analyse and understand process variables, to determine a process’s capability to perform with respect to those variables, and to monitor the effect of those variables on the difference between customer needs and process performance.

Control Charts does this by allowing a manager to identify and understand sources of variation in a process and hence to manipulate and control those sources to decrease the difference between customer needs and process performance. This decrease can be managed only if the process under study is stable and capable of improvement.
Common Cause Variation is due to the process itself. Process capability is determined by inherent common causes of variation such as poor hiring, training, or supervisory practices; inadequate lighting; stress; management style, policies and procedures; or design of products and services. Special Causes of Variation are due to events external to the usual functioning of the system.

A control chart is a very useful process monitoring technique; when unusual sources of variability are present, sample averages will plot outside the control limits. This is a signal that some investigation of the process should be made or corrective action to remove the unusual sources of variability taken. Systematic use of a control chart is an excellent way to reduce variability and thus stabilize the process.

Rules for Identifying Out-of-Control Points:

- **Rule 1**: A process exhibits a lack of control if any subgroup statistic falls outside of the control limits.
- **Rule 2**: A process exhibits a lack of control if any two out of three consecutive subgroup statistics fall in one of the A zones or beyond on the same side of the centreline.
- **Rule 3**: A process exhibits a lack of control if four out of five consecutive subgroup statistics fall in one of the B zones or beyond on the same side of the centreline.
- **Rule 4**: A process exhibits a lack of control if eight or more consecutive subgroup statistics lie on the same side of the centreline.
- **Rule 5**: A process exhibits a lack of control if eight or more subgroup statistics move either upward or downward in value.
- **Rule 6**: A process exhibits a lack of control if an unusually small number of runs above and below the centreline are present.
- **Rule 7**: A process exhibits a lack of control if thirteen consecutive points fall within zone C on either side of the centreline.

Zones:

- **Zone A** = Centerline +/- 3 times sigma
- **Zone B** = Centerline +/- 2 times sigma
- **Zone C** = Centerline +/- 1 times sigma

Where sigma is the standard error calculated.

Types of Charts:

- **Attribute Charts**
  - Classification Charts
• **p chart** – The *p chart* is used to control the fraction of items with a certain characteristic. Subgroup sizes in a *p chart* may remain constant or vary. A *p chart* may be used to control defective vs. conforming.

• **np chart** – The *np chart* serves the same function as the *p chart* except that it is used to control the number rather than the fraction of items with the characteristic and is only used with constant subgroup sizes.

  o **Count Charts**

  Count charts deal with the number of times a particular characteristic appears in some given area of opportunity.

  • **c chart** – A *c chart* is used to control the number of times a particular characteristic appears in a constant area of opportunity. A constant area of opportunity is one in which each subgroup used in constructing the control charts provides the same area or number of places in which the characteristic of interest may occur.

  • **u chart** – A *u chart* serves the same basic function as a *c chart*, but it is used where the area of opportunity changes from subgroup to subgroup.

• **Variable Charts**

  o **x-bar and R charts** – Used with subgroup size of 2 or 3 when the cost of sampling is relatively high; they are also typically used with subgroup sizes of 4-9.

  o **x-bar and s charts** – are generally used with subgroup sizes of 10 or more.

  o **Individuals and Moving Range Chart** – are used when only one variable measurement is available or appropriate as a subgroup.

*(Gitlow et al. 2005)*

Advantages of achieving a stable process:

✓ Management knows the process capability and can predict performance, costs, and quality levels.

✓ Productivity will be a maximum and costs will be minimized

✓ Management will be able to measure the effects of changes in the system with greater speed and reliability.

✓ If management wants to alter specification limits, it will have the data to back up its decision

A common desire of many control chart users is to be able to state a process’s ability to meet specifications in one summary statistic. Such statistics are available and are called process capability indices. We use these indices to summarize internal processes as well as vendor processes.

A capability index is a single statistic (index) used to state a process’s ability to meet specifications.
Cp: This index is used to summarize a process’s ability to meet two-sided specification limits. The Cp index assumes that the process average is centred on the nominal value.

Cpk: This index is used to summarize a process’s ability to meet two-sided specification limits when the process is not centred on nominal.

CPU: This index is used to summarize a process’s ability to meet a one-sided upper specification limit.

CPL: This index is used to summarize a process’s ability to meet a one-sided lower specification limit

(Gitlow et al. 2005)
2.2 Chosen Techniques

The major difference between Theory of Constraints and Lean Manufacturing is that they focus on different objectives, which technically are not that different. Lean Manufacturing focuses on eliminating waste whereas Theory of Constraints focuses on increasing or improving throughput. Technically, these two techniques or tools compliment each other rather than oppose one another. According to Goldratt, the ultimate goal is to make money. However, this is attained by eliminating wastes such as excessive inventory work force. Thus Lean Manufacturing also indirectly has its aim at improving profit.

Ultimately, in both perspectives, whether it is TOC or Lean, the net profit is calculated by finding the difference between the throughput and the operating expense. Therefore, either eliminating waste or increasing throughput will give the same result of an increasing profit.

Theory of Constraints was the chosen technique in solving ShelvCraft’s problem of schedule delays, however, Lean Manufacturing was in effect also used to compliment this chosen technique. The reason however, why TOC was chosen as the base technique is because ShelvCraft’s problem lies more in an undesired throughput rate than wastes with regards to the processes involved in the manufacturing of these two products namely, “Bolt & Nut Shelving” and “Stackable Basket Sets” and also because ShelvCraft works with different transfer and process batch sizes as applied in TOC whereas Lean focuses on equal batch sizes.

The chosen technique used to solve ShelvCraft’s Quality Management problem was the use of control charts as it is quite a necessity, not to just improve processes but also for management to have complete control and constant knowledge of how the processes are performing.
3 Chapter 3: Methodology

3.1 Model Presentation

3.1.1 Control Charts and Process Capability

The chosen technique used to address ShelvCraft’s problem of inconsistency between customer requirements and process performance was the use of control charts, both attribute and variable, as well as process capability indices and cause-and-effect diagrams.

Attribute and variable control charts were utilised in order to identify whether defects or defective items present in the system were caused by special or common cause variation and further observe these processes in order to eliminate these causes of variation by the continuous improvement process of quality management, keeping in mind not to let inertia become the system constraint.

Once the charts were drawn up to identify the type of variations present in the process, a further step was taken to model the special cause variations on fish-bone (ishikawa diagrams) in order to establish the cause and effects present.

In so doing, the causes can be eliminated and/or prevented in the future.

Once a stable process is established by eliminating these special causes of variation, the process capability can be measured using process capability indices to give the company an idea of how capable the process is to adhere to requirements.

3.1.2 Constraint Elimination for Improved Throughput

The schedule delays experienced by ShelvCraft approached by taking into account the routes of all products that influence the routes of the constrained products. This is called the “Bill of Routes” of the various products. This is necessary in calculating the amount of available time on each resource for the amount of available time allocated to these various products will be made aware of.

Once the routes are identified and dependence of products on certain resources acknowledged, the particular times required of each resource by the products need to be obtained. These times include set up times, production/operation times, batch sizes, demands etc.

When all of this data is obtained, an excel spreadsheet will be formulated where distinct formulas can be used to identify where to constrained resources are and how much time they still require.

A trade off analysis will then be taken in objective to obtain the most feasible alternative or solution to this bottleneck.

(Appendix Section 4.1 Table 3 & 4)
3.2 Model Implementation and Analysis

3.2.1 Elimination of Schedule Delays

Dr. Eliyahu Goldratt’s theory of constraints (TOC) was the chosen technique used to address ShelvCraft’s problem of the schedule delay experienced by the product items: “Bolt & Nut Shelving” as well as the “Stackable Basket Sets”

ShelvCraft is currently producing an average of 100 units per day whereby the demand is 150 units per day for the “Bolt & Nut Shelving”

ShelvCraft is currently producing 150 units per day whereby the demand is 180 units per day for the “Stackable Basket Sets”

The Appendix has the “Bottleneck Identification Process” that was undertaken in the following way:

(Appendix Section 4.1. Table 3)

With the relevant data that was obtained from ShelvCraft, such as the; Bill of Routes, set up times, production times and demands for products that had an influence on the production rate of the constrained product, as well as for the constrained product itself, an excel spreadsheet was opened up in order to formulate an algorithm that will calculate which resources were slowing down the production process.

Using ShelvCraft’s Bill of Routes, information was obtained as to which resources (the route taken) the “Bolt & Nut Shelves” go through from raw steel sheets up to finished product. The machines that made up this route were identified. Other products that went through these same machines at any stage of their production process were then identified. Information regarding set up times, production times, batch sizes, demands etc. of these products as well as the constrained product were then obtained in order to gain knowledge of how much time each product requires of each resource.

1) The various resources obtained from this route were listed.

2) The products that form a part of this route were listed.

3) Set Up times as well as Production (Operation) Times were noted.

4) The Set Up time for the washing process is a once of process and only noted once instead of for every product.

5) The daily demands of each product was obtained and documented.

6) The available time for each Resource per day is 480 minutes (8 hours).

7) Total time required per day per resource was calculated as follows: Operation time per product per resource multiplied by the demand per product, plus the set up time per product per resource.
8) This total time was then compared to the available time per resource per day and thus the bottlenecks were identified as resources that required more than the available time of 480 minutes per day.

(Appendix. Section 4.1. Table 3)

This process shows that there are 3 constrained resources:

1) The PEGA-357
2) The Washer
3) The Powder Coating Process

Of these three constrained resources (bottlenecks), “The Washer” was the most constrained and thus according to Theory of Constraints, this resource was tackled first.

Possible ways of eliminating this bottleneck are:

1) Buy a new machine.
2) Make machine operators work overtime, and in so doing increase the available resource time.
3) Outsourcing the process.

Option 1: Buy a New Machine

Trade off analysis was applied in order to conclude what would be the most feasible solution. Buying a new machine would require taking into account the purchase price for the new equipment as well as the depreciation costs per period of time.

Buying a new machine would roughly cost R90 000 and depreciation at ShelvCraft is done using the straight line method. The equipment is said to depreciate at a rate of 20% per annum.

Other direct costs, such as direct material and direct labour form part of this trade off calculation in the difference in costs as there will be extra materials and labour costs.

(Appendix Section 4.1. Table 4)

Option 2: Increase Available Resource Time

In order to increase available resource capacity to achieve the required time, the available time would need to be doubled. At the moment the factory operates from 8 am to 5 pm, working a double of that would mean working from about 6am – 10 pm without a lunch break therefore ShelvCraft would require to hire more employees and work on a shift basis. Weekends will be taken into consideration for this calculation in order to minimize the working hours during the week. The possible solution to eliminating the bottleneck completely would be to work from 7am-6pm on weekdays as well as working during the lunch hour and working from 6am- 7pm on weekends, also using the lunch hour. This option could mean skating on thin ice with regards to following policy or
labour law if shifts are not worked out appropriately. If shifts are however worked out appropriately this is a positive option to the country due to extra job creation.

The overtime rate for employees is 1.5 times the normal hourly rate. Electricity rates for operation of the machinery will also increase the current electricity bill by approximately 0.1 times. As per usual, electricity is paid hourly.

**Option 3: Outsourcing**

Outsourcing is another alternative solution that was considered, however, this method of eliminating the bottleneck is a concern to ShelvCraft as they believe this introduces a risk to the company of losing customers, or revealing trade secrets to the company doing the outsourcing. As ShelvCraft have information leading to believe that the demand of the “Bolt and Nut Shelve” is bound to increase over the next couple of years, outsourcing their products and giving another company their potential profit is not an option they are completely comfortable with.

Outsourcing costs were taken into consideration and the Trade off analysis can be viewed in more detail in the Appendix as to which alternative serves as the most economically feasible solution for this constraint.

*(Appendix Section 4.1. Table 4)*

**Trade off Analysis**

According to ShelvCraft’s forecast data, the demand for the "Bolt and Nut" Shelve is to increase at a rate of 20 daily units per year, beginning in 2011. Therefore the demand in 2011 will be 170 units, the demand in 2012 will be 190 units and the demand in 2013 will be 210 units. Not only is the demand of the “Bolt and Nut” shelving said to increase but also that of the “Rivet Shelving” as well as the stackable baskets sets. The washing process is a necessary process common to most of ShelvCrafts items, basically any product made of steel will require to be washed and then powder coated. Considering the fact that demand of these basic products is said to increase with ShelvCrafts ongoing growth and expansion, investing in a second washing process seemed to be most logical thing to do. However, a trade off analysis was done incorporating the various costs, and this can be viewed on Table 4 in the Appendix.

After trade off analysis was undertaken, the most economically feasible solution was shown to be, in order of most profitable to least profitable:

1) Outsourcing

2) Working Overtime

3) Buying a New Machine

*(Appendix Section 4.1. Table 4)*
The next most constrained resource will then be the PEGA-357 which is only behind schedule by 1 hour and the Powder Coating Process is behind schedule by 15 minutes. Trade off Analysis need not be done here as it is only logical to rely on working overtime in these cases.

An alternate option in production of the “Stackable Basket Sets” was observed to be the following:

Once the lengths have been spot welded, they get put onto the floor. The time it takes for spot welding per unit according to the computer is +/- 160 seconds. A single operator that cuts off the overlapping edges after the panels are taken off the spot welding machine, comes up the stairs from a location that’s a approximately 70m from the spot welding machine and collects these welded panels in quantities of approximately 2. He then walks back down to cut them. This is an ongoing process. He travels +/- 140 m in order to collect 2 panels for trimming. This serves as a possible reason for the schedule delay as the production of “Stackable Basket Sets” are not meeting the current demand of 180 units per day.

The “Wiring Process” is done upstairs. The factory layout should be modified by moving the trimming machine upstairs since it is not required for any other processes. There is adequate space and it will not place an operator under an added risk or hazard as far as health and safety is concerned. This will eliminate the distance travelled from 140 m to approximately 2m and thus reduce time wastage as well as energy usage and muscular effort. The distance on its own is a productivity limitation; the fact that there’s a difference in levels of ground where the dependent machine is situated, makes this more of a limitation and drawback with regards to productivity.

### 3.2.2 Quality Control

An inspection process was undertaken where wounded coil is unwound and cut into specified lengths. The inspection was conducted on a 3mm diameter coil that was cut into lengths of 1m each. When coil is cut into specified lengths -these lengths are used within the factory and not sold to consumers, hence tolerance specifications are set by the company themselves. Control Charts for the process of cutting 3mm wire into lengths of 1m were drawn.\(^2\)

Upper Specification Limits are set a lot more relaxed than Lower Specification Limits as the excess lengths are usually trimmed off in final finishing touches after the wire lengths have been transformed into finished product parts. Lower Specification Limits are set very tight as wires that are too short can become completely defective and therefore unusable in the necessary processes. It is advisable that these wires not be scrapped but used in products where smaller lengths are required. Wastage of part of the length is always better than scrapping the entire length.

The chosen chart is the x-bar and s chart as there are 10 observations per subgroup and more than 10 subgroups.

Figure 4 is the s-chart of the cutting process of 1m lengths from 3mm (in diameter) coils. The lengths are not always exactly 1m, and this chart shows the process variability. Sub-group number 5 seems to be out of control due to special cause variation as it opposes the first rule of the commonly

\(^2\) Appendix Section 4.3. Figure 4
applied set of rules to investigate whether a process is out of control. This rule states that a process is out-of-control if any data point falls outside of the control limits.

(Appendix. Section 4.3. Figure 4)

Before the x-bar chart can be drawn, the s-chart must first be stabilized.

Brainstorming was conducted with 2 operators, the floor manager, one of the brothers owning the company as well as myself. The brainstorming was a quick, 10 minute session and was done on possible causes of this out-of-control process. The following possible causes resulted:

- Breakdown of Machine
- Erroneous Set up
- End of Coil
- Faulty/Broken Stopper
- New, inexperienced operator
- Measurement device inaccurate

A Check Sheet was drawn and can be found in the Appendix.

(Appendix Section 4.1. Table 2)

This check sheet shows that there are 16 points or 16 lengths of wire that fall below the lower specification limit established by the company. This is not a good result as falling beyond the lower limit is more severe than going beyond the upper limit as mentioned above. The wiring will unusable in its intended process and will need to be used in the smaller length category causing wastage due to trimming.

Inspection on average production time of this same process was undertaken but on different days and timeslots, hence the previous result is not dependent on this one. The chosen chart was the x-bar and R chart as this chart is used for subgroup sizes of two or three when the cost of sampling is relatively high; they are also typically used with subgroup sizes of four through to nine. The R-Chart was then drawn, which can be found under Figure 5 in the Appendix.

(Appendix Section 4.3. Fig. 5)

This process is out of control as it exhibits characteristics of the following two rules

1) A process exhibits a lack of control if any subgroup statistic falls outside of the control limits

3) A process exhibits a lack of control if any four out of five consecutive points fall in one of the B zones or beyond

Data point 1 falls under rule number 1 and data points 4, 5, 6 and 7 fall under rule number 3. This process therefore exhibits a lack of control.
As priorly done on the first inspection, brainstorming was conducted here as well with the following results:

- New inexperienced operator
- Deliberate idling by operator
- Machine breakdown
- Incorrect set up
- Set up time erroneously added into production time
- Mechanical Fault

The Ishikawa Diagram was used to find possible causes for assignable (special) cause variation. The diagrams can be found in the Appendix.

(Appendix Section 4.3. Figure 6 & 7)

The average production times\(^3\) seem to vary tremendously especially, subgroup 1 due to the fact that ShelvCraft does not employ a specialised operator to do the cutting. The cutting of wounded coil into lengths seems to be a rather simple task and thus no specialised operators are really required. ShelvCraft shift operators about, in order to have coil cut, and sometimes the operator working on the dependent process comes in, sets the machine up for a batch then goes back to his job. This also wastes time and delays the dependent machinery. It was concluded that during the batch with the extreme production time, there was a machine breakdown, the wiring got stuck into the machine and the inexperienced operator had to then go and find the manual to the machine and after great difficulty and wasted batch run due to the fact that the breakdown/fault was not properly sorted, the machine was up and running in almost 4 times the average production time.

From the second Ishikawa diagram\(^4\), we see that the lengths diverge from the nominal value due to the fact that the stopper was inaccurate. The machine is old and wearing out and should consider being replaced after calculating the trade-offs. The previous control chart was also affected by a machine cause even though it also is related to inexperienced operators.

Since the assignable causes were found and could be rectified, the existing chart could have been used. However, new control limits were calculated, for more clarity and stricter control.

(Appendix Section 4.3. Figures: 8,9,10 and 11)

The process is now stable and hence the process capability can be calculated.

\[
\begin{align*}
Cp & \text{: } \frac{USL - LSL}{6\sigma} & \text{where USL stands for Upper Specification Limit} \\
CPU & \text{: } \frac{USL - \bar{x}}{3\sigma} & \text{LSL stands for Lower Specification Limit}
\end{align*}
\]

\(^3\) Appendix Section 4.3. figure 5

\(^4\) Appendix Section 4.3. figure 7
The following values were obtained on application of the above formulae:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cp</td>
<td>1.5523</td>
</tr>
<tr>
<td>CPU</td>
<td>2.61239</td>
</tr>
<tr>
<td>CPL</td>
<td>0.49222</td>
</tr>
<tr>
<td>Cpk</td>
<td>1.5523</td>
</tr>
</tbody>
</table>

According to the Empirical Rule, a process capability index of 1.0 indicates that a process will generate virtually all of its output within specification limits. According to the normal distribution, a process capability index of 1.0 indicates that a process will generate 99.73% of its output within specification limits. Any index above 1.0 makes the process that much more capable. Therefore this process is now very capable. However, continuous improvement can similarly be undertaken.

### 3.2.3 Pile up at Powder Coating Machine

Dr Eli Goldratt’s novel “The Goal” puts emphasis on whether robotics or automation really is a benefit to the company. Has the introduction of automation increased productivity of the firm? Taking the powdering process into consideration, three questions were asked, each of these three questions relating to one of the factors to the ultimate goal from the operations point of view.

1) Has automating the powdering process sold more products than when this process was undergone manually?

2) Has this powdering robot decreased operations expense by allowing the company to let off employees?

3) Has work-in-process inventory gone down?

Yes certainly according to reports, mechanization of the powdering process has increased productivity and efficiency in the manufacturing of certain products. It has increased throughput to an extent of these products. However, the throughput rate is still not as efficient as required by the company. How can this be improved? As noted, only certain products have benefited from this automation, therefore there are some products of which the productivity rate has deteriorated and due to this, this process starts to depict characteristics of a bottleneck.
Take for instance, the powder coating of “Stackable Baskets Sets”. The baskets are hung upon the line that moves at a speed of approximately 0.1 m/s through the enclosed powder coating container and the output rate is approximately 1 every 30 seconds assuming the process is perfect. Once a single load of these baskets are completed, then only, can a different product be hung onto the line. This thus, increases the pile up of unfinished products awaiting the powder coating process.

This automation has also not encouraged the letting off of employees, assumable to union laws. This process has been automated, yet there are still 5 employees at the powder coating “track”, 3 of which are observed to be idle.

Hence,

1) Work-in-process inventory has not gone down- Pile up of products requiring an automated powder-coating more necessarily than others.

2) No employees have been let off since the introduction of this automation

3) Thus, this process has ultimately not sold more products

Automation, and thus technology, is not necessarily always an improvement, and therefore it is advised that this concept should be shaken off.

Smaller products such as the “Stackable Baskets Sets” are advised to be powder-coated using a different method, i.e. dipping into containers and hanging to dry. This process will produce an output rate of approximately 1 every 5 seconds and simultaneously decrease waiting time of bigger products such as “Wire Mesh Lockers” which are most efficiently powder-coated using the current method.

1) This will cause more products to be sold.

2) Work-in-process inventory will have decreased.

3) As for the letting off of employees, this is now not necessary as they can be used in the new proposed manual method of powder-coating. This at least, does not leave our resources idle.

“Use your people or lose them”

*(Goldratt, 2004)*
3.3 Recommendation

ShelvCraft should advisably outsource in order to eliminate the schedule delays as this is the most economically feasible option. However, if the company is strongly against this option the next best option would be to work overtime on a shift basis as this not just the next most profit favouring option but also implements job creation.

A formula-only based spreadsheet is made available as in Table 5 of the Appendix Section 4.1. This will assist ShelvCraft in continually change the changing demand of products and in so doing continually be observant for new bottleneck formations.

A recommendation to continually draw up control charts in not just this process but all processes in order to give the firm indication on whether their processes are in control or out and where the problem lies, in so doing giving a better understanding of why the issue lies in the particular area. With continuous use of control charts, continually observation and effort can be made to ensure that the process is always stable and with that comes the advantages a stable process as mentioned above.

A ready-to-use control chart will be implemented for ShelvCraft on request.
3.4 Conclusion

There are various ways of eliminating a bottleneck, there are always alternative solutions. Trade off analysis, can be done using many tools and techniques, to obtain the most feasible solution.

Feasibility can lie in many areas, whether it be economic feasibility, practical feasibility, technological feasibility etc. The ultimate goal is to obtain a solution that fits the problem most suitably, that suits the company most suitably, taking into consideration their most highly weighed feasibility option.

Prior to obtaining a solution to the problem, the problem has to be found. The reason for the problem has to be sought and thus there included a bottleneck identification process within this report.

Quality Assurance is an important factor in the production industry. Quality is the key to a good reputation and a good reputation is the key to a successful business. Control Charts not only improve quality be generates a form of control which ultimately creates confidence within the company as they are in control and know where they stand.

Just as the implementation of control charts gives visibility creating confidence, so will the implementation of an excel sheet to constantly keep track of whether there are and where there are bottlenecks within the firm.
Reference

- “The Goal” by Dr Eliyahu M. Goldratt. Revised Publication, 2004
- A simulation comparison of traditional, JIT, and TOC manufacturing systems Cook, David P, Production and Inventory Management Journal; First Quarter 1994
- Integrating Discrete-Event simulation with statistical process control charts for transition in a manufacturing environment, Harriet Black Nembhard, Ming-Shu Kao and Gino Lim, 1999
4 Appendix

4.1 List of Tables

Table 1: Demand List for Products

This is the Daily Demand of Products Manufactured at ShelvCraft

<table>
<thead>
<tr>
<th>Product</th>
<th>Daily Demand (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stackable Basket Sets</td>
<td>180</td>
</tr>
<tr>
<td>Large Stackables</td>
<td>120</td>
</tr>
<tr>
<td>Gondola 1524 High 457 Base</td>
<td>10</td>
</tr>
<tr>
<td>Wire Smart Shelve Unit</td>
<td>10</td>
</tr>
<tr>
<td>Flea Market Basket</td>
<td>N/A</td>
</tr>
<tr>
<td>Magazine Stand Wire Smart</td>
<td>N/A</td>
</tr>
<tr>
<td>Dump Bins</td>
<td>N/A</td>
</tr>
<tr>
<td>Medium &amp; Heavy Duty Racking</td>
<td>N/A</td>
</tr>
<tr>
<td>Bolt &amp; Nut Shelving</td>
<td>150</td>
</tr>
<tr>
<td>Boltless Prepacked Shelving</td>
<td>60</td>
</tr>
<tr>
<td>Rivet Shelving</td>
<td>100</td>
</tr>
<tr>
<td>Wall Shelving</td>
<td>40</td>
</tr>
<tr>
<td>Gondola Shelving</td>
<td>20</td>
</tr>
<tr>
<td>Display Solutions</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The N/A demand values are those that are too small on a daily basis to be regarded relevant.

Table 2: Check List

<table>
<thead>
<tr>
<th>CHECK SHEET</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>below LSL</td>
<td>16</td>
</tr>
<tr>
<td>0.995-0.999</td>
<td>12</td>
</tr>
<tr>
<td>1.000-1.003</td>
<td>21</td>
</tr>
<tr>
<td>1.004-1.007</td>
<td>29</td>
</tr>
<tr>
<td>1.008-1.011</td>
<td>13</td>
</tr>
<tr>
<td>1.012-1.015</td>
<td>0</td>
</tr>
<tr>
<td>1.016-1.019</td>
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<tr>
<td>1.036-1.04</td>
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<tr>
<td>above USL</td>
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</table>
# TABLE 3: Bottleneck Identification

<table>
<thead>
<tr>
<th>Operation</th>
<th>Machine</th>
<th>BNS001</th>
<th>RS001</th>
<th>PPBS001</th>
<th>WS001</th>
<th>A22406</th>
<th>A22295</th>
<th>A22376</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punching</td>
<td>PEGA-357</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>540</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bending</td>
<td>BEND S</td>
<td>1</td>
<td>1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.6</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>BEND A</td>
<td>1</td>
<td>1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.6</td>
<td></td>
<td></td>
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<td>Assembly</td>
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<td>455</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PP</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wash</td>
<td></td>
<td>34</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>986</td>
</tr>
<tr>
<td>Coat</td>
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<td>1.7</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Every Machine has 8 hours available per day, therefore the available time in minutes for every machine is 480 minutes.*

Key:
- BNS001: Bolt & Nut Shelf
- RS001: Rivet Shelf
- PPBS001: Pre-Packed Boltless Shelf
- WS001: Wall Shelf
- A22406: Wire Smart
- A22295: Wire Smart
- A22376: Stackable Basket Sets

Note: The wash process consists of 5 stages that total 34 minutes and complete 20 units at a time, thus we obtain 34/20 = 1.7 minutes per unit, regardless of the product type.
## TABLE 4 – Trade Off Analysis

### Buy New Machine

<table>
<thead>
<tr>
<th>Expenses</th>
<th>Income</th>
<th>Approx Long term Income (Cys)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Cost (R)</td>
<td>90000</td>
<td></td>
</tr>
<tr>
<td>Depreciation @ 20% p/a</td>
<td>18000</td>
<td>21500</td>
</tr>
<tr>
<td>Direct Materials @ R 40 day *</td>
<td>5280</td>
<td>45000</td>
</tr>
<tr>
<td>Direct Labour increases @</td>
<td>46400</td>
<td>25200</td>
</tr>
<tr>
<td>Total yearly cost</td>
<td>73680</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td>22980</td>
<td>12500</td>
</tr>
<tr>
<td></td>
<td>25000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127000</td>
<td>186300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Profit 5332</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long Term 11262</td>
</tr>
</tbody>
</table>

### Overtime - working weekends as well

<table>
<thead>
<tr>
<th>Expenses</th>
<th>Income</th>
<th>Approx Long term Income (Cys)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday overtime 3.5 hrs @ R</td>
<td>10150</td>
<td>21500</td>
</tr>
<tr>
<td>Weekend overtime 13 hrs @ R</td>
<td>17576</td>
<td>45000</td>
</tr>
<tr>
<td>Weekend +/- 104 days</td>
<td>23400</td>
<td>22980</td>
</tr>
<tr>
<td>Supervisory</td>
<td>23400</td>
<td>12500</td>
</tr>
<tr>
<td>Total yearly cost</td>
<td>51126</td>
<td>25000</td>
</tr>
<tr>
<td></td>
<td>127000</td>
<td>186300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Profit 7587</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long Term 13517</td>
</tr>
</tbody>
</table>

### Outsourcing

<table>
<thead>
<tr>
<th>Expenses</th>
<th>Income</th>
<th>Approx Long term Income (Cys)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation @ R 73 pl/day</td>
<td>16936</td>
<td>21500</td>
</tr>
<tr>
<td>Labour @ R 65 per item</td>
<td>19500</td>
<td>45000</td>
</tr>
<tr>
<td></td>
<td>36436</td>
<td>25200</td>
</tr>
<tr>
<td></td>
<td>22980</td>
<td>12500</td>
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<tr>
<td></td>
<td>570</td>
<td>100 units 25000</td>
</tr>
<tr>
<td></td>
<td>25000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127000</td>
<td>186300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Profit 9056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long Term 14986</td>
</tr>
</tbody>
</table>

**Note:** Only a difference in the amounts are shown and not the actual amounts.
4.2 The Production Process- constrained products
This production process only defines the processes and machines used in routes that constrain the two identified delayed items namely, “The Bolt & Nut Shelving” and “Stackable Basket Sets”

**Punching (Cutting):** Heavy duty punching is done on one of two machines, either the PEGA-357 or the ELGA.

**Bending:** There are about 5 bending machines each used for difference in type of bending required, whether it be heavy or light duty, complex or simple bending

**Welding:** There are a few spot welding machines, however there are currently only two being used in the route that’s been focussed on

**Washing Process:** The washing process is a 5 stage process that is a requirement for almost all steel products. It consists of:

- **Degreaser:** +/- 15 minutes
- **Cold Water Rinse:** +/- 1 minute
- **Phosphate Rinse:** +/- 15 minutes
- **Cold Water Rinse:** +/- 1 minute
- **Rustop:** +/- 2 minutes

**Powder Coating:** This is the final stage for most steel products where the washed steel is powder coated (applied with a coat of paint) in an automatic application system
4.3 List of Figures
Figure 4: s-chart Production Lengths
Figure 5 : R-chart for Production Times
Figure 6: Cause-Effect Diagram for Production Times
Figure 7: Cause-Effect Diagram for Variation from Nominal Value
Figure 8: Production Lengths after elimination of special cause variation
Figure 9: Production Lengths after elimination of special cause variation
Figure 10: Production Times after elimination of special cause variation
Figure 11: Production Times after elimination of special cause variation
4.4 Company Catalogue
The company catalogue can be found in the hard copy