A Lean Six Sigma approach for improving the changeover time on a packaging line at South African Breweries Limited

by

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Executive summary

South African Breweries Limited (SAB) is distributer of beer and soft drinks to Southern Africa. Chamdor Brewery is situated in the south west of Gauteng and produces not only beer but alcoholic fruit beverages like Redds, Sarita and Brutal Fruit. Fulfilling the demand of such a variety of products offered by SAB requires flexibility while producing round the clock. Quick changeovers enable manufacturers to be flexible while maintaining high efficiency rates for equipment. The aim of this project is to provide suggestions for reducing the changeover time for a specific packaging line at Chamdor Brewery using a structured improvement methodology called DMAIC (Define-Measure-Analyse-Improve-Control). Literature was gathered to help understand the problem and relevant techniques that could aid in the problem solving process. Information was collected during each stage of the project for use in each specific tool which in turn defined the major problems of the process. Solutions to these problems were developed and presented to the management and owners of the process. The implementation of this project is not in the scope of this project but rather left to the process owners to decide if the solutions will be implemented.

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1. Introduction

1.1 Background

South African Breweries Limited (SAB) is a subsidiary of SABMiller plc and is one of the world's largest brewers by volume. The annual brewing capacity of SAB equals 3.1 billion litres (Rebelo 2003) and includes top selling brands like Carling Black Label, Hansa Pilsener, Castle Lager, Castle Lite and Castle Milk Stout. SAB has 47 sites in total, seven breweries and 40 depots. Chamdor brewery produces niche brands which includes flavoured alcoholic beverages (FABs) as well as premium beers (Anon 2005).

Chamdor brewery has different packaging lines that are designed to pack different brands and sizes of bottles. Some of these packaging lines are multi-pack lines, meaning they can pack different brands and different sizes on the same line as required. Line 7 at Chamdor brewery is a multi-pack line that can accommodate only new bottles (non-returnable bottles). New bottles that are packed on this line include 275ml, 330ml, 340ml and 440ml non-returnable bottles (NRB).

When different brands or sizes of bottles are changed on the packaging line it is known as a changeover. Changing between brands with the same size bottle is known as 'Brand' changes and changing between different sized bottles are known as 'Pack' changes. Different Brand/Pack combinations throughout the production schedule involve changing parts of machines in the packing line to facilitate the new Brand/Pack with the correct raw material and correct processing method. Changing from one Brand/Pack to another results in downtime of the line which is not desirable for a high volume producer.

Changing Brands or Packs are unavoidable for a multi-pack line and thus reducing these set-up times are crucial for the company to stay competitive. By reducing the time of these changeovers the line will have more production time available.

1.2 Literature Review

1.2.1 Overview of quick changeovers

Manufacturing companies producing high volumes of different kind of products have in the past been forced to produce large lot sizes in order to minimise equipment downtime. With today's modern technology available and increased customer demand for products to be available on request, ensuring that various different products are available requires smaller lot sizes and less downtime of equipment. This means performing a quick changeover. A quick changeover can be described as the technique of reducing the amount of time to change a process from one specific type of product to another (Kilpatrick 2003).

Quick changeovers have numerous benefits to a company who can perform this task quickly and consistently with minimum errors. Some benefits from a quick changeover include increased flexibility, reduced downtime and fewer defects. Some case studies reports show vast improvements in the changeover time by following a lean technique like Ingle Minute Exchange of Die (SMED). A case of a steel tool manufacturer in the USA reports that a cutting die operation needed frequent changes of the die in one day. By lining up spare dies next to the cutting cell, changeover time was reduced from 60min to 11min (P. Tong 2009). Thus a lean technique like SMED, which was originally developed by Shingo (1985), should be applied to the packaging line of SAB.

The Six Sigma methodology is a structured approach to enhance process performance and achieve high levels of quality while maintaining low levels of variability (Salah et al. 2010). The term Six Sigma essentially means to have a process of which 99.99966% of the products are statistically free of defects or 3.4 defective products per million. Define-Measure Analyse-Improve-Control (DMAIC) is the steps created by Motorola to achieve Six Sigma (Salah et al. 2010). Each step represents a phase that consists of a number of tools and techniques that must be completed before moving on to the next phase.

The integration of lean manufacturing and the Six Sigma methodology is common place to many companies today striving to gain as much benefit from each different toolset. This integration of the two methodologies is described as Lean Six Sigma (LSS) and can be seen as a methodology to eliminate waste and reduce variation (Salah et al. 2010). By using a LSS approach to reduce changeover time the variation between different changeovers will be reduced with Six Sigma while reducing the overall changeover time with lean tools like SMED.

1.2.2 SMED: A lean tool for quick changeovers

Single-minute exchange of die (SMED) is a lean manufacturing methodology developed by Shigeo Shingo to aid in improving changeover performance. In practicing SMED the goal is to reduce the time it takes to change a line or process from running one product to the next product (Alexa 2011). The concept of SMED is to reduce set up times to less than 10 minutes, but in essence *Single-minute* means to reduce a changeover process to a one-figure number measured in minutes (Alexa 2011). Change over performance is measured in minutes but determining when a changeover starts and when it is finished can vary depending on the person measuring the changeover. A definition to establish the time a changeover represents is described as the time that passes between the last good part manufactured in the previous series up until the first good part is manufactured in the present series (Alexa 2011). This definition of a changeover time will also be used for this project.

Changeover processes consists of many different elements or tasks that need to be done on the machines to run the new product. These set-up elements can be categorised to either internal or external elements (Burcher et al. 1996). Internal elements are activities that need to be performed while the machine is stopped while External Elements are activities that can be performed while the machine is running (Alexa 2011). Internal elements consume capacity of the process and affect the output, therefore to reduce the effective set-up times there is one of two options available: either use dedicated machines which will eliminate set-up completely or move the internal elements to external set-ups (Burcher et al. 1996). Therefore applying SMED to a machine or production line, the goal is to move as much of the Internal elements to external elements and to eliminate activities that are of no use (Alexa 2011). If more activities can be performed while the machine or production line is running, the machine or production line can be stopped for a shorter period and this will results in less downtime.

Different types of set-ups exist for different products meaning set up time is not fixed for each product. For example if different beer brands are changed but the bottle size stays the same, the only differences between the products would be the labels, crowns and beer. But if a different size bottle is used, many other parts may need to be changed to accommodate the new size. By scheduling the production schedule to allow similar set-ups sequentially, changeover time may also be minimised (Burcher et al. 1996).

The SMED methodology consists of 4 conceptual stages as describe by Shingo in which improving a process is defined, this includes the Preliminary Stage: ‘Internal and external setups are not distinguished’, Stage 1: ‘Separating internal and external setup’, Stage 2: ‘Converting internal to external setup’ and Stage 3: ‘Streamlining all aspects of the setup operation’ (Shingo 1985). Another sequence of the SMED method is described by Alexa and includes five phases (Alexa 2011):

- Phase 0 “The Choice of subject”
- Phase 1 “Observations and measurements”
- Phase 2 “Bettering the present situation”
- Phase 3 “The change of low-cost production means”
- Phase 4 “Important changes of the production means”

These phases represent the same idea as the 4 stages of Shingo but provide a better explanation of how to perform the SMED system. Phase 0 is the identification of a process on which the SMED method can be applied, this is followed by Phase 1 where internal and external operations are identified (Alexa 2011). Phase 2 is described by extracting the external operations performed as internal operations followed by Phase 3 where internal operations are transformed into external operations usually by means of a technology input (Alexa 2011). Phase 4 is the last phase and requires reducing the time of each internal and external operation and usually requires some reconsideration of the manufacturing process (Alexa 2011).

1.2.3 Six Sigma

As mention before, Six Sigma is a methodology that aims for continual quality improvements and reducing variability within a process. The steps to achieve Six Sigma are called DMAIC. These improvement phases must be performed in a sequential order to achieve the goal of Six Sigma. Each phase has a specific goal in order to solve the problem with an array of tools that accompanies each phase. Several different literatures about following the DMAIC process exists with each one explaining the detail of each phase differently and giving different tools to complete each phase.

Define

The Define phase is where the apparent problem will be identified and scoped to ensure that every person that is part of the Six Sigma project clearly understands the objective of the project. Another definition of the define phase can be described as the identification of the specific problem and defining project goals and deliverables (J. P. C. Tong et al. 2004). The Define phase involves scores of problems, such as project selection and planning, production and service planning, training and education planning, resource allocation and investment decision making (Tang et al. 2007). Some of these scores have already been done like project selection because of the known problem at the company. Other scores like education planning may not be present in this project because of limited time and scope. Some tools that are used as part of the Define phase are the defining of the problem statement, preparation of a project charter, the analysis of the previous best state and the timing and resource planning of the project with a Gantt chart.

The problem statement is a document used to identify the problem before a project charter is compiled. The process under consideration is identified and the problem areas in the process and scope of the process must be defined. The definition of how the specific process will be measured must also be clearly defined with the problem statement. The project charter is a document that summarises the whole project. It contains a condensed problem statement, the process definition, the objective of the project, the scope and boundaries of the process, possible benefits to the identified customer and a schedule of when the phases must be completed.

The analysis of the best state can be done with historical data and the goal of this analysis is to determine the previous best state that the process has achieved. This can be used as target value to improve the process average to this value. The project Gantt chart is used to plan the execution of the project and to serve as a project tracker to ensure all the tasks and activities are performed on time as planned.

Measure

Measure is the phase where the selected process will be properly defined by measuring the current state of the process. A different definition of the measure phase states reviewing the measurement system and the key features included (J. P. C. Tong et al. 2004). It also involves developing operational definitions for each characteristic of the system, collecting initial data for capability studies and performing studies to validate the measurement procedure (Gitlow et al. 2005). The basic result of the Measure phase should provide information about the process capability, a process map and the definition of the measurement system to be used. Typical tools that are used in this phase will include a process map, a Cause and Effect Matrix, collection of the initial data for a capability study and basic statistical calculations.

The process map is a diagram that shows the sequence flow and order of events or tasks. This may also include machines to show the logical flow of a production process. A macro process map usually shows the general flow of products through a whole assembly line while a micro process map will usually show the inputs and outputs to a particular sub process. The Cause and Effect matrix is a tool to help identify the most important inputs that affect a certain output. Each process is identified with all the different inputs that affect the output of the specific process, and then each input is given a rank with regards to how much this input affects the output of the process. This is used to identify the most significant inputs that affect the outputs. The initial data can either be new data gathered or usually historical data of the process. Capability indices can then be calculated to establish the current performance of the process. The basic statistical calculations are used to determine the shape and spread of the data and to check normal statistical calculations like average and standard deviation.

Analyse

The next phase in the DMAIC methodology is the Analyse phase. This phase is done to determine the relationship between the key output variables and the corresponding input variables affecting the performance of these outputs. Specific statistical methods and tools are used to determine the key contributing factors that affect the performance of the process (J. P. C. Tong et al. 2004). A key aspect in this phase is to reduce the number of input factors affecting the process to only the inputs that highly affect the process performance. Some tools used in this phase are the Failure Mode and Effects Analysis (FMEA) and Multi Vari Planning (MVP).

FMEA is used to determine the high risk inputs of a process and ways each input can fail. This tool uses the outputs of the Cause and Effect matrix as inputs and determines each variables effect on the process, the possibility to occur and decision methods of such a variable if it may occur. A Multi-Vari Plan is a tool used to determine the relationship between the input variables relating to the output variables. Process data is recorded during normal operation of the process. The aim is to see the effect of each different input variable on the output with normal variation included.

Improve

The Improve phase of the DMAIC methodology is where any intentional changes to the process are made to quantify the suspected relationships between key input and output variables. This phase can also be described where key factors that cause the problem are discovered (J. P. C. Tong et al. 2004). Critical inputs are actively manipulated with experiments in this phase to determine the output. Design of Experiments (DOE) is one of the key tools in this phase. At the end of this phase a Should-Map of the process can be developed.

DOE is used to actively intervene with the process to test modified input parameters to the process. The designed experiments are used to study the effect on the output of the process. Carefully designed experiments will provide valuable information to positively improve the process. A Should-Map can be drawn after a successful DOE exercise has been completed. This new Should-Map must provide a revised process map of the new recommended procedure and sequence of events.

Control

The last phase of the DMAIC methodology to achieve Six Sigma is called the control phase. This phase is primarily for maintaining the gains achieved throughout the whole project. The processes that create the product must be controlled and continuously monitored to ensure that the problem does not occur again (J. P. C. Tong et al. 2004). Thus establishing a control plan to continue with the new best practises is vital to ensure that all the effort of the project is not lost. Controlling consists of mistake-proofing the new practices and standardising successful process revisions in training manuals (Gitlow et al. 2005). In the control plan, a measurement plan must also be established to ensure the future monitoring of the process. This is a key aspect to help sustain the gains achieved in the improve phase and to quickly establish any deviations from the newly established standard. Without a monitoring plan the whole project may divert back to the previous approach and the effort with the project will be a waste.

2. Define

In this section the methods, tools and techniques are described which was used in the project. The first four stages of DMAIC namely Define, Measure, Analyse and Improve was followed. The control phase is excluded since the aim of the project is limited to the making of suggestions. The process owners have the authority to implement these suggestions and thus the decision lies with them to implement and control these solutions.

2.1 Project aim

The aim of this project is to make suggestions on possible solutions that can reduce the packaging line changeover time with minimum variability in time between different changeovers. Quality is of highest importance and thus any suggestions should have no negative impact on the quality of the products.

The benefits of improving the changeover time can include:

- Increased efficiencies and throughput.
- Increased brand pack reliability. The daily commitment to Central Planning will be met.
- Waste reduction, there is ± 1000 bottles lost on every changeover.

2.2 Project scope

The scope demarcates processes affected by this problem and to be addressed and focussed on by the project.

The scope of this project includes:

1. This project is limited to only Line 7 at Chamdor Brewery.
2. The process boundary is from the depalletiser receiving new bottles up until the palletiser.
3. Changeover time is measured from the time the last good bottle from the "old" Brand/Pack exits the filler up until the next bottle of the "new" Brand/Pack exits the filler at full rated speed.
4. Downtime from any machines downstream from the filler resulting in the filler stopping or slowing down due to changes made during a changeover should be added to the change over time.
5. The process ends when the "new" Brand/Pack reaches the palletiser.
6. All different variations of brand/pack changeovers will be considered, this include:

Old Brand	New Brand	Change Type
330ml	330ml	Brand
340ml	340ml	Brand
275ml	275ml	Brand
340ml	275ml	Pack
340ml	330ml	Pack
340ml	440ml	Pack

Table 1: Brand and pack changes type

7. Change part management (organising different parts for different products)
8. Machine setup

The following are not included in the scope of the project:

1. Warehouse operations
2. Any breakdown operations during a changeover.

It will be assumed that all raw materials will be available on request during the whole project. The basic functions of the packaging line are shown in Figure 1. This shows the broad scope of where the focus of the project will fall.

Figure 1: Basic process overview

2.3 Problem statement worksheet

The problem statement worksheet is the tool to formally identify the problem, the specific process that is affected and the scope of the process into which further study will be done. This was done with the process owner which is the line 7 unit manager. This gives an outline of the specific problem and the scope of this problem. This tool was used early in the project to define the “Project aim” and “Project scope” as listed under the introduction section of this document. Table 2 shows the answers to the relevant questions as provided by the unit manager.

This formed the basis for the project to make sure that all relevant processes were considered and to ensure that the correct problem is being addressed. The next step was to conduct a high level process map to identify the key processes in the changeover process.

Process Name	What is the process that you are trying to improve?
Chamdor Line 7 Brand/Pack change over time	
Process Definition	How would you define the process?
The process involves the change from one Brand/Pack on the packaging line to another. The objective of the project is to ensure the Brand/Pack changeover is done in the shortest possible time.	
Process Scope	What are the boundaries that you would put around the process?
1. This project is limited to only Line 7 at Chamdor Brewery. 2. The process boundary is from the depalletiser receiving new bottles up until the palletiser. 3. The process starts as soon as the filler stops filling and the plan are to change either the Brand or Pack. 4. Changeover time is measured from the time the last good bottle from the “old” Brand/Pack exits the filler up until the next bottle of the “new” Brand/Pack exits the filler at full filler rated speed. 5. Downtime from any machines downstream from the filler resulting in the filler stopping or slowing down due to changes made for brand/pack should be added to the change over time. 6. The process ends when the “new” Brand/Pack reaches the palletiser. 7. All different variations of Brand/Pack changeovers will be considered, this include: 7.1. NRB to NRB (Different brand, same pack) 7.2. NRB to NRB (same brand, different pack) 8. Change part management 9. Machine setup What is not in the scope of the project: 1. Warehouse operations 2. Any breakdown operations during a changeover.	
Customer Identification	Who are the customers of the process?
Chamdor Packing manager, Chamdor Line 7 Unit Manager	
Problem Statement	What are the problems associated with the process.
The Brand/Pack changeover time for Line 7 at Chamdor is taking too long and causing at least one of the 7 wastes, "waste of waiting time", to occur. The process of changing over involves running one specific Brand/Pack and changing either the same Brand/Pack or to a different one. Quality will be the counterbalance to this problem, meaning quality cannot be affected in the process of reducing the changeover time.	
Is it Specific?	How do these problems impact the business?
Brand/Pack change over times are recorded on shift bases as downtime are used as part of the Efficiency calculations. And when rolled up with the other downtime recordings they pull the Efficiencies measure down below the target value by year end.	
Is it measurable?	What could we measure to demonstrate that the problems are improved?
Brand Pack change over is measured and recorded as part of daily production data by the relevant operators and collated by the team leader on a shift bases.	
Is it achievable?	What are the targets for the measurement
To reduce Brand Pack change over time up to < X minutes between Brand/Pack changes	
Is it relevant?	If these problems are improved, how will our customer benefit?
Internal customer: will benefit by achieving Efficiency targets. External customers: will benefit through more Brand Pack reliability. Financial gains may also be possible, but will need to be accurately estimated at a later stage.	

Table 2: Problem statement worksheet

2.4 Process map: high level

The high level process map describing the flow of bottles and listing the major component of this packaging line is presented below in Figure 2. This was compiled by observing the flow of bottles through the process and talking to operators and team leaders working with the machines. This process map describes how each machine is positioned in the packaging process with the aim to identify the key machines contributing to change over time.

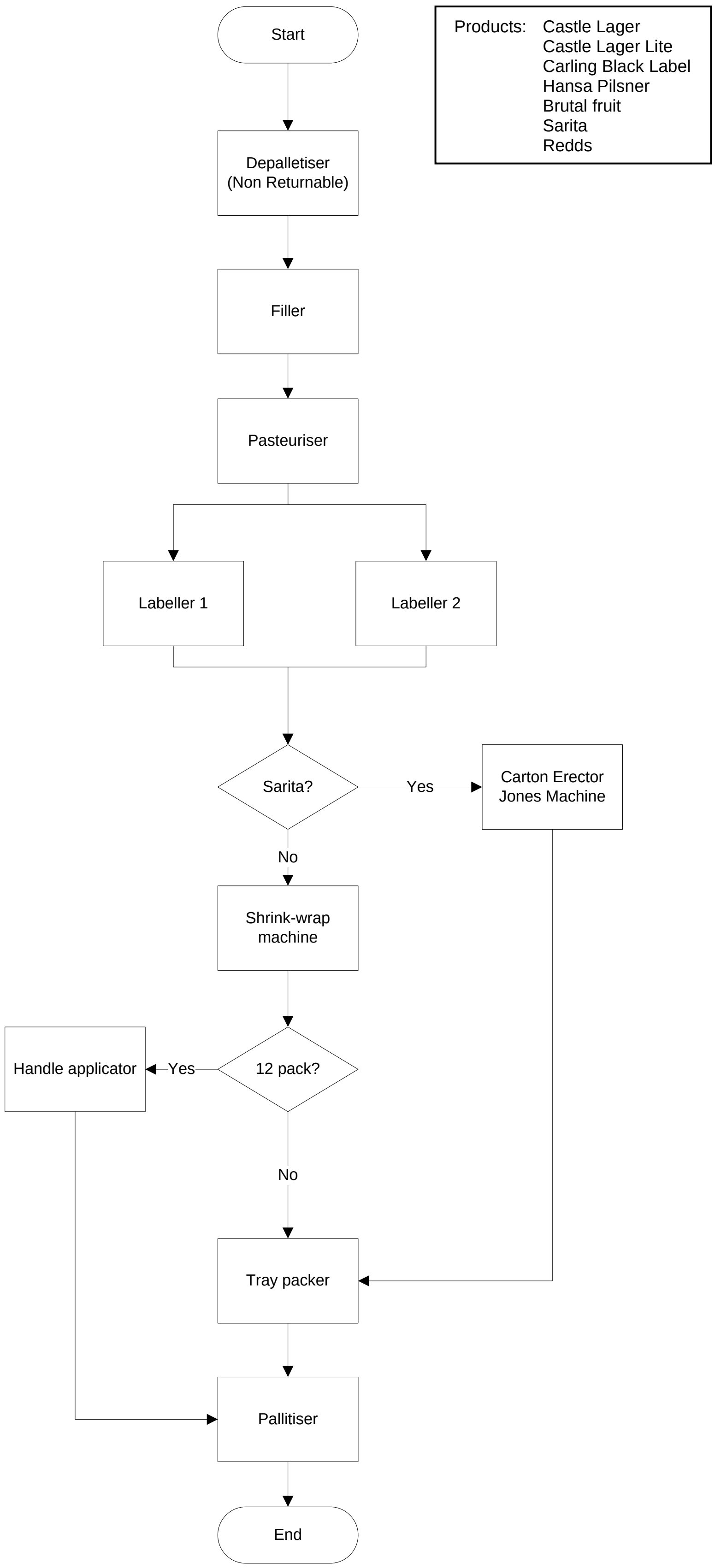


Figure 2: Process map high level

The filler, pasteuriser and two labeller machines are a given path for all bottles but the remaining path of the bottles is dependent on which brand is being packaged.

Each machine has its own changeover procedure with some machines more complex than others. Some machines like the pasteuriser and carton erector machine do not have changeover activities, for example the carton erector is only used with the Sarita brand and the pasteuriser automatically changes temperature according to the brand being run, thus no changeovers occur at these machines. It is thus needed to focus on the machines with the biggest influence on changeover time and the subsequent tools focus on identifying those machines.

An example of how a product flows through the line can be described as follow: if Castle Lager six packs are being packed the flow of these bottles will start at the depalletiser. The new empty bottles will then be rinsed, filled and crowned at the filler machine. This is followed by a pasteurisation stage at the pasteuriser and then labelled at either one of the labellers. Castle lager has a plastic packaging and is sent to the shrink-wrap machine. It bypasses the 12pack handle applicator machine and proceeds to the tray packer which packs trays with 4 six packs or 24 bottles. These tray units are then sent to the palletiser where the trays are stacked in a specific pattern to create one pallet. One can see that if any of the two Sarita brands are being packed, the bottles are diverted to the carton erector machine instead of the shrink-wrap machine followed by the tray packer and palletiser. If any of the 12 pack brands are run the tray packer are completely skipped and diverted straight to the palletiser after it has been shrink wrapped and the handle is applied. Thus many different variations of this sequence can exist depending on the brand and pack which will be produced next.

3. Measure

The measure phase included three tools that were used to evaluate the current state of the packaging line and to identify the key area to focus on. Historical data analysis was done to establish the current performance of the packaging line and to estimate a target value for the project. A low level process map was created to identify all relevant inputs and outputs to each main process described in the high level process map. These low level inputs were then used to formulate a Cause and effect matrix (C/E) to further narrow down the inputs which have the biggest influence on changeover time.

3.1 Historical data analysis

Due to unforeseen circumstances this project was originally started at SAB Alrode brewery line 11 and was moved to Chamdor brewery line 7. Historical data analysis was initially done with data provided by Alrode brewery but unfortunately data for Chamdor line 7 was recorded for brands and packs that is not being produced on that line anymore and sufficient data analysis was not possible. Data that is applicable to the current brands that is being produces at Chamdor line 7 was in short supply and very few data points were available to analyse the data sufficiently. Therefore it was decided to show the initial data analysis of Alrode line 11 and to highlight the methods used in that analysis, as well doing the same data analysis on the limited data available on Chamdor line 7.

3.1.1 Data Analysis: Alrode line 11

Line 11 at Alrode brewery is a much older line than Chamdor line 7. That particular packaging line produces only beers which include returnable and non-returnable bottles. Dumpies are classified as 340ml non- returnable bottles (NRB) and 330ml bottles are classified as returnable bottles (RB). 7 months of historical data from the May 2010 until January 2011 was provided by Alrode for analysis. This data for line 11 at Alrode Brewery showed the changeover time for the filler machine and the labeller machines. The most recent data for changeovers were not available because data were not recorded after this time. The provided data only included data for the filler machine and labeller machines because according to managers of line 11 these two machines contribute the most to the total changeover time. The other set up changes to the rest of the packaging line seemed to have little effect on the changeover time.

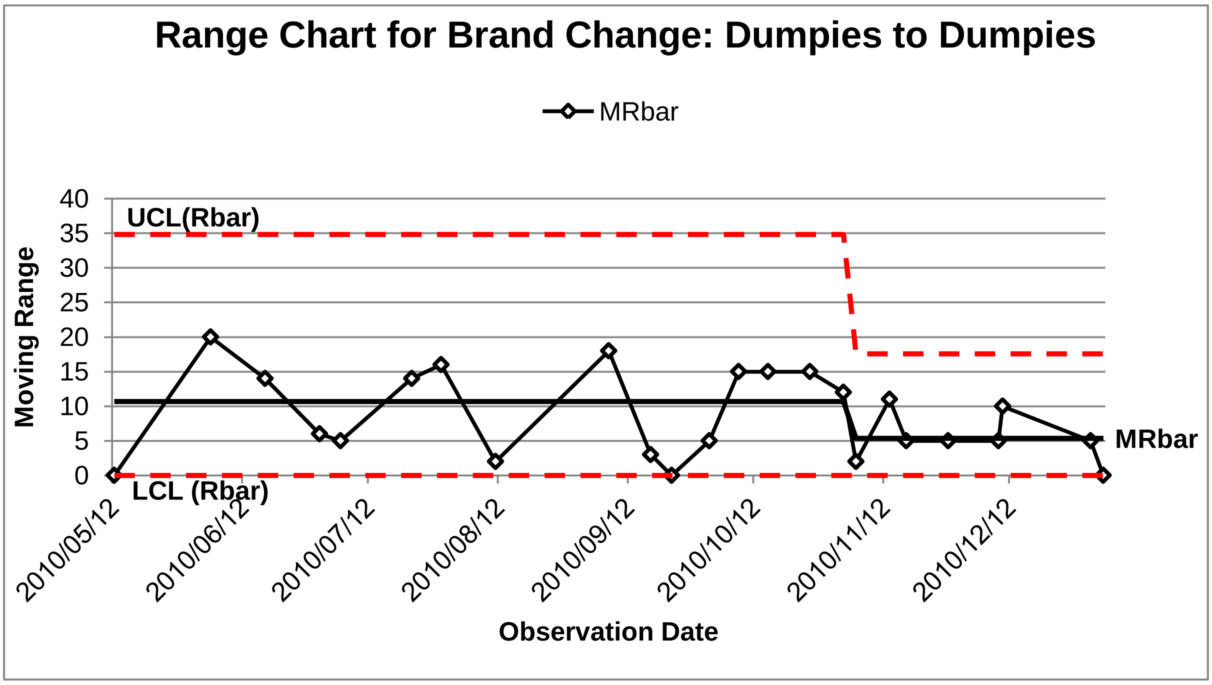
Data was recorded for each different changeover, either a Brand change or Size change. When Brand changes occur they are of either a Dumpies to Dumpies change or Pints to Pints Change. Dumpies to Dumpies changes include switching from Castle Lite to Castle Lager or Castle Milk Stout and vice verse. Pints to Pints changes include switching from Hansa, Castle Lager or Black Label to any one of the other three mentioned and also vice versa. Size changes usually take longer according to the data provided and include changes between Pints and Dumpies and Miller Genuine Draft (MGD) to Dumpies. MGD bottles are 355ml in size and thus differ from both Dumpies and Pints.

Control charts for each different change was compiled with their corresponding data set. Moving range charts were developed with the provided data and analysis of each are provided in the following sections. The Xbar charts contain two extra lines, the threshold line and target value lines. These lines represent the current upper control limit and target value that SAB has assigned for this process.

3.1.1.1 Dumpies to Dumpies

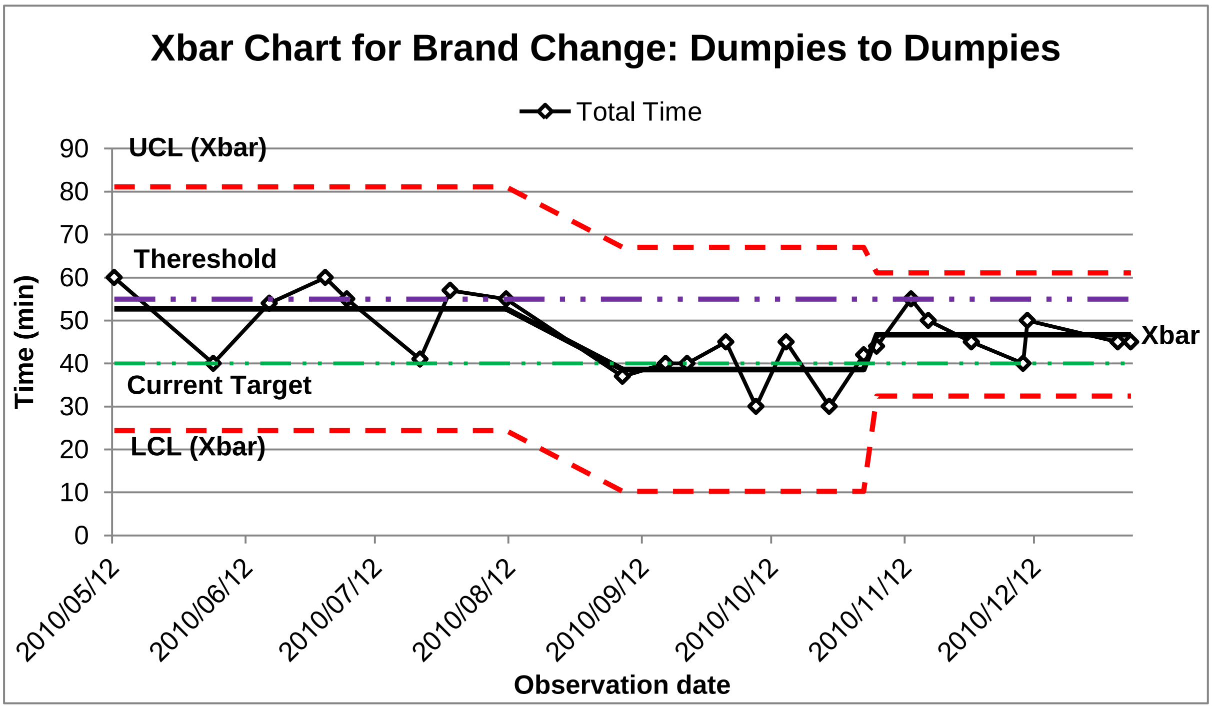
Dumpies are non-returnable bottles with a size of 340ml. Each range chart contains an upper and lower control limit with an average line also plotted. The control limits and average has been recalculated in some of the charts to show the progression of variation and the average over time. These charts with different calculated control limits and averages show a good picture of the instability of the corresponding process.

The range chart of the Dumpies to Dumpies change as shown in Graph 1 shows a constant pattern with the last part of the chart showing smaller differences between values. This indicates that the variation of the process can be improved. The range average jumps from 10 to 5 which also indicate that the range average reduced to a value of 5min.



Graph 1: Range Chart for Dumpies to Dumpies

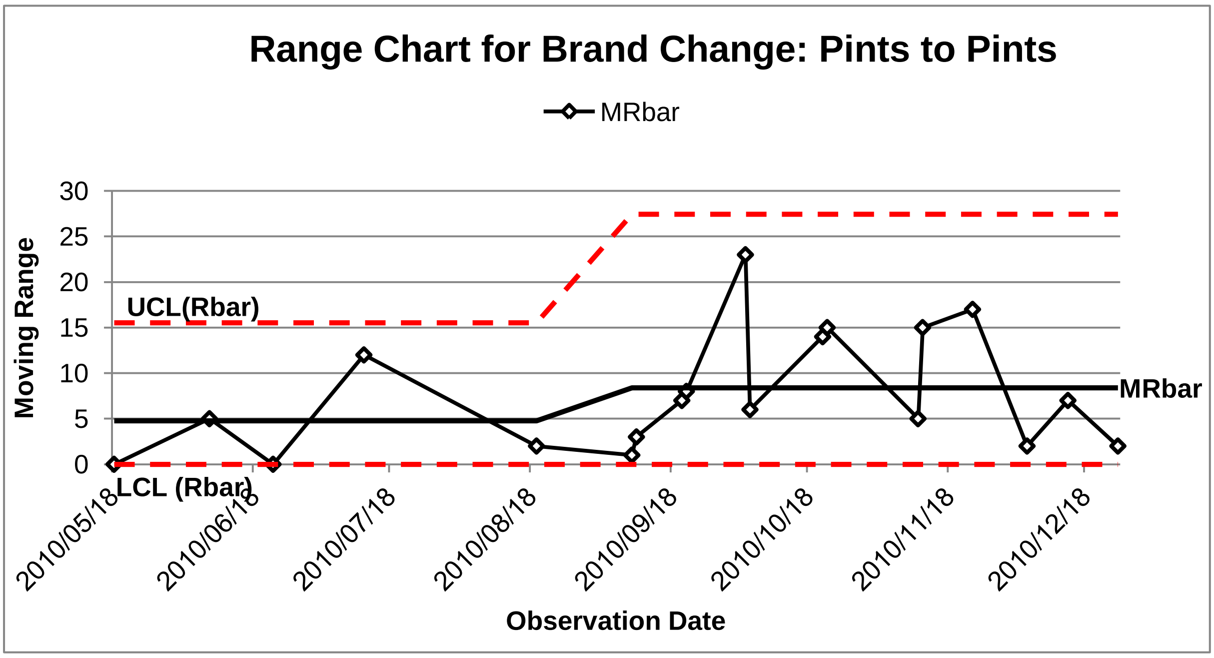
The Xbar chart for the Dumpies to Dumpies changes displayed in Graph 2 shows that the process average is not consistent over time. It can be clearly seen that the process average run on three different values throughout the 7 month period with the best average running just under 40 minutes. This indicates that improvement is needed on this process. There are also quite a number of points above the threshold line in the first few point of the graph.



Graph 2: Xbar chart for Dumpies to Dumpies

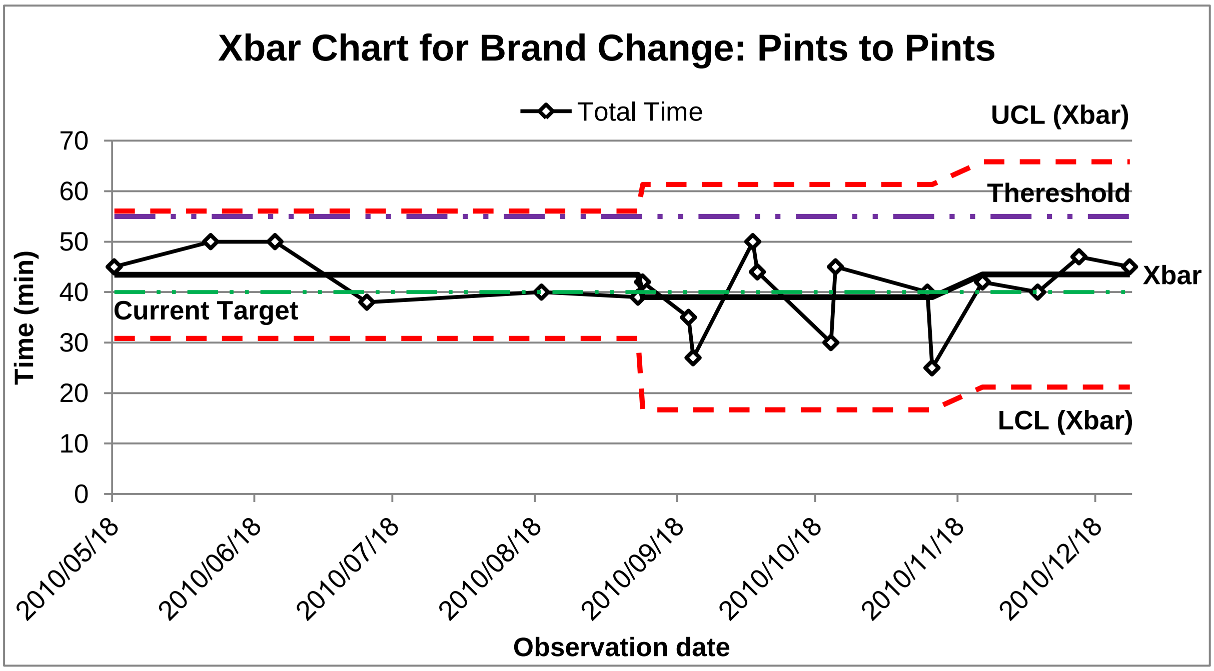
3.1.1.2 Pints to Pints

Pints are returnable bottles with a size of 330ml. The same charts as for the Dumpies have been drawn below. The range chart shown in Graph 3 indicates that the process variation is quite high towards the end of the chart and might be because of some external factors affecting the changeovers.



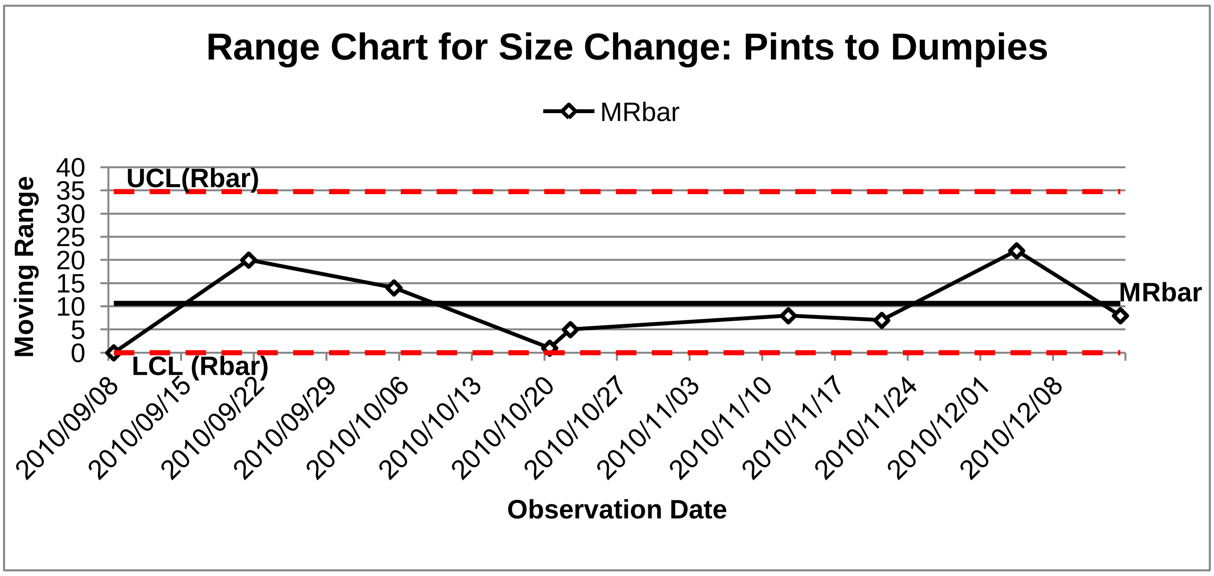
Graph 3: Range chart for Pint to Pints

The Xbar chart of the Pints to Pints shown in Graph 4 also shows an inconsistent process average and very high variation towards the end of the process. This shows that the process is not under control. There is however a number of data points very low on the graph. This shows that the process has capability to run on lower averages.



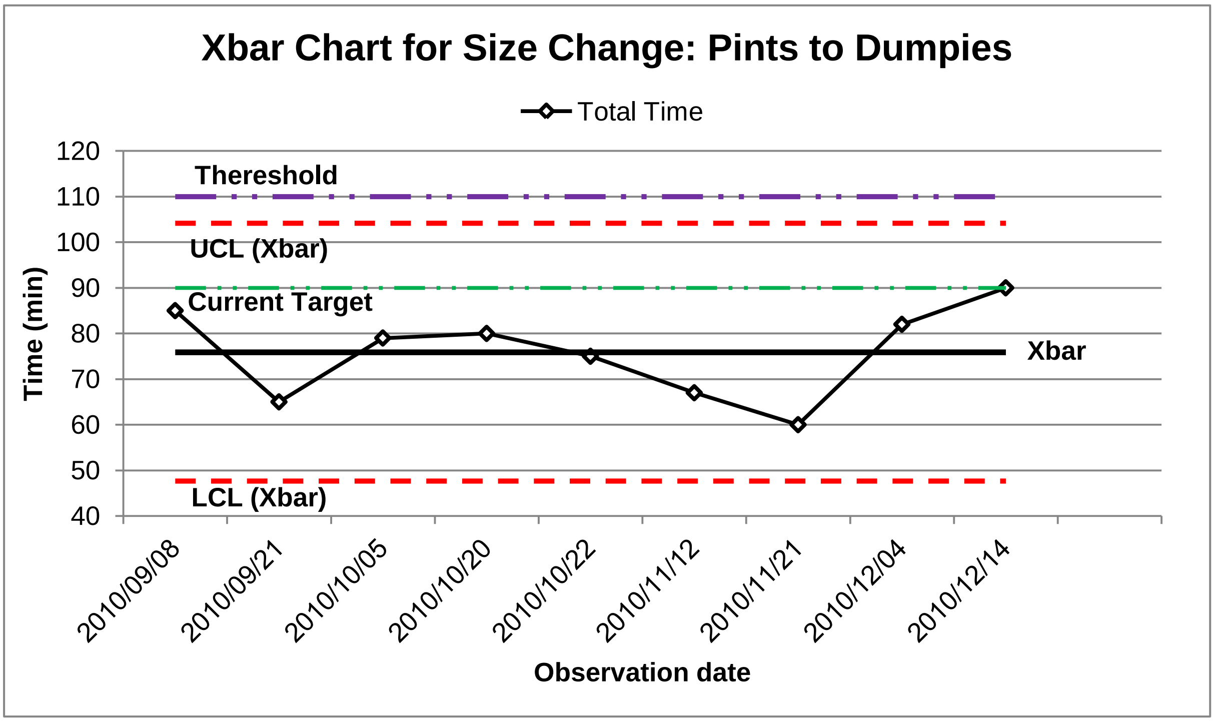
Graph 4: Xbar chart for Pints to Pints

3.1.1.3 Pints to Dumpies



Graph 5: Range chart for Pints to Dumpies

Pints to Dumpies involve changing more parts due to a different bottle size. The range chart of the Pints to Dumpies changes, Graph 5, shows a higher average range than a brand change. This shows that this process has too much variation and must be improved to reduce this inherent variation.

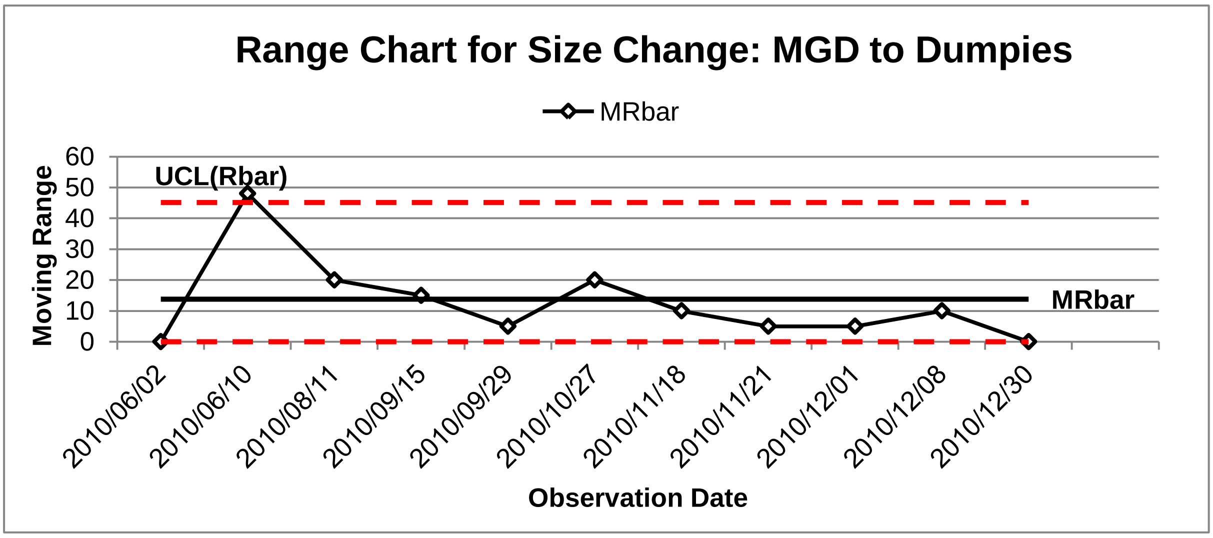


Graph 6: Xbar chart for Pints to Dumpies

The Xbar chart for Pints to Dumpies changes, Graph 6, show that the process average is below the target value. This means this process is performing satisfactory under the current target value and threshold set by SAB for this process. There is however still great variations between the points which can be reduced.

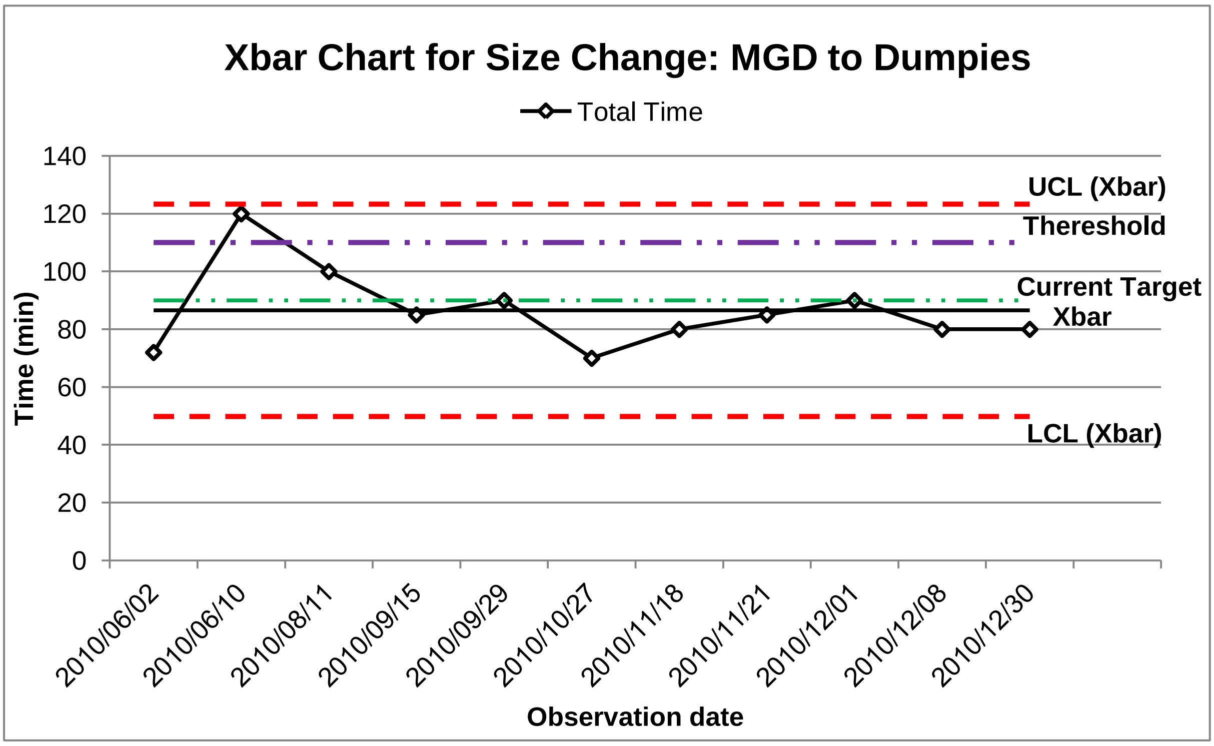
3.1.1.4 MGD to Dumpies

The range chart for MGD to Dumpies changes, Graph 7, show a high range average, which means there is still lots of variation in the process that may be eliminated. But this high average may be because of the high point in the beginning of the chart. The rest of the chart looks under control.



Graph 7: Range chart for MGD to Dumpies

The Xbar Chart for the MGD to Dumpies changes, Graph 8, show that the process is operating just under the target value of 90min. There is still some variation present in the process and the lower points indicate that the process average can be improved.



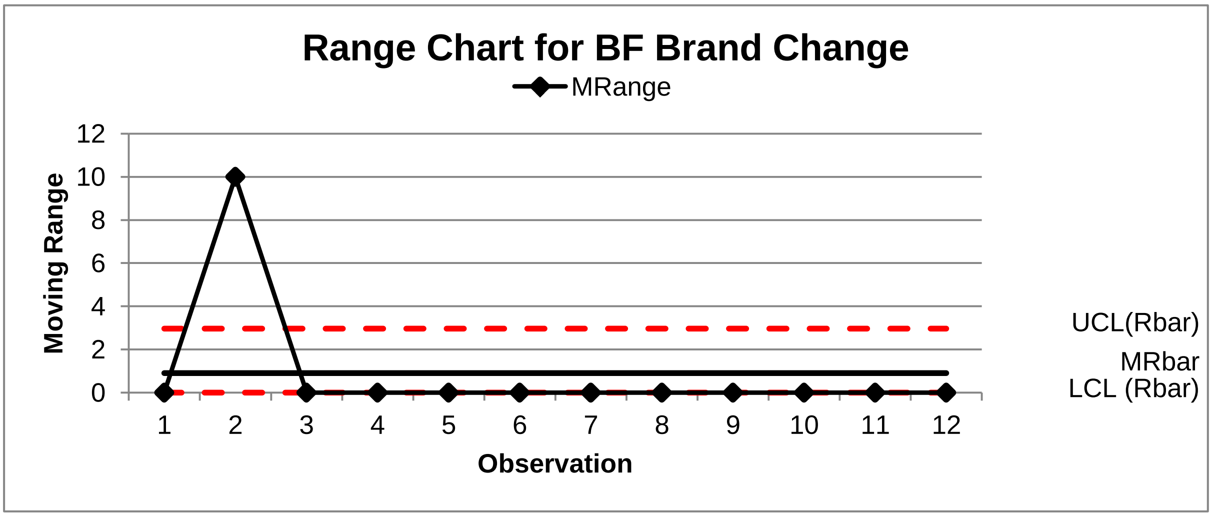
Graph 8: Xbar Chart for MGD to Dumpies

3.2 Data Analysis: Chamdor line 7

The only data available for line 7 was that of Brutal Fruit, Redds and Sarita. The data had much less detail and showed only if a brand or pack change was conducted, it did not state from which specific brand was changed to the next specific brand or pack. The data was also recorded without logging a date. This data is the most recent pulled from the system, but the exact dates of these data points are not known.

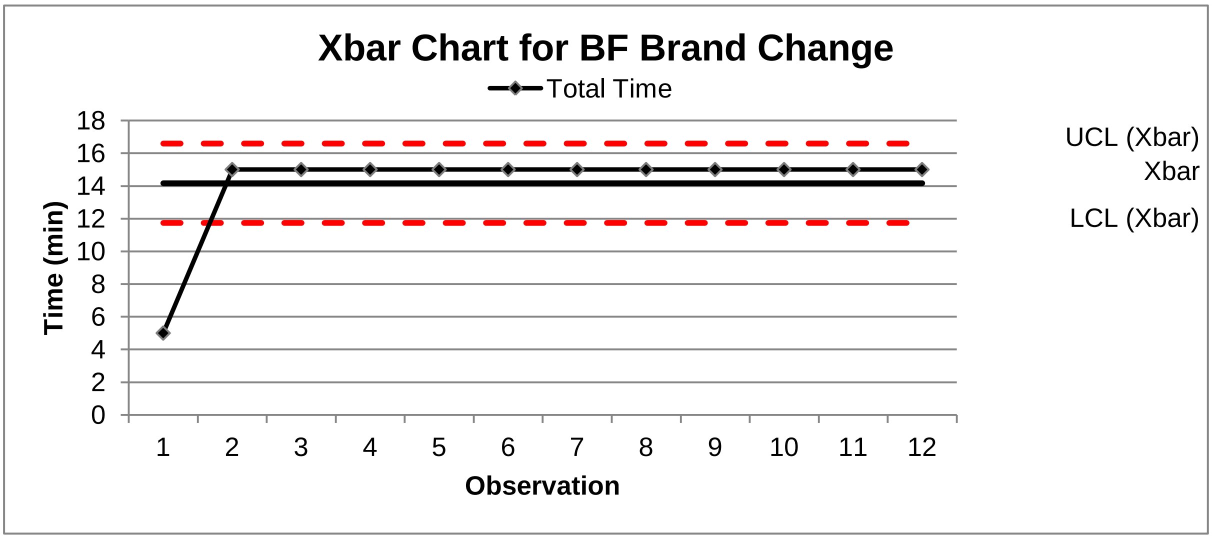
3.2.1.1 Brutal fruit brand change

The brand changes for brutal fruit consist of changing between different brutal fruit flavours. Any other changes will be a pack change because the bottle geometry differs from any other product. Graph 9 shows the range chart and Graph 10 shows the Xbar chart for brutal fruit brand changes.



Graph 9: Range chart for Brutal Fruit brand change

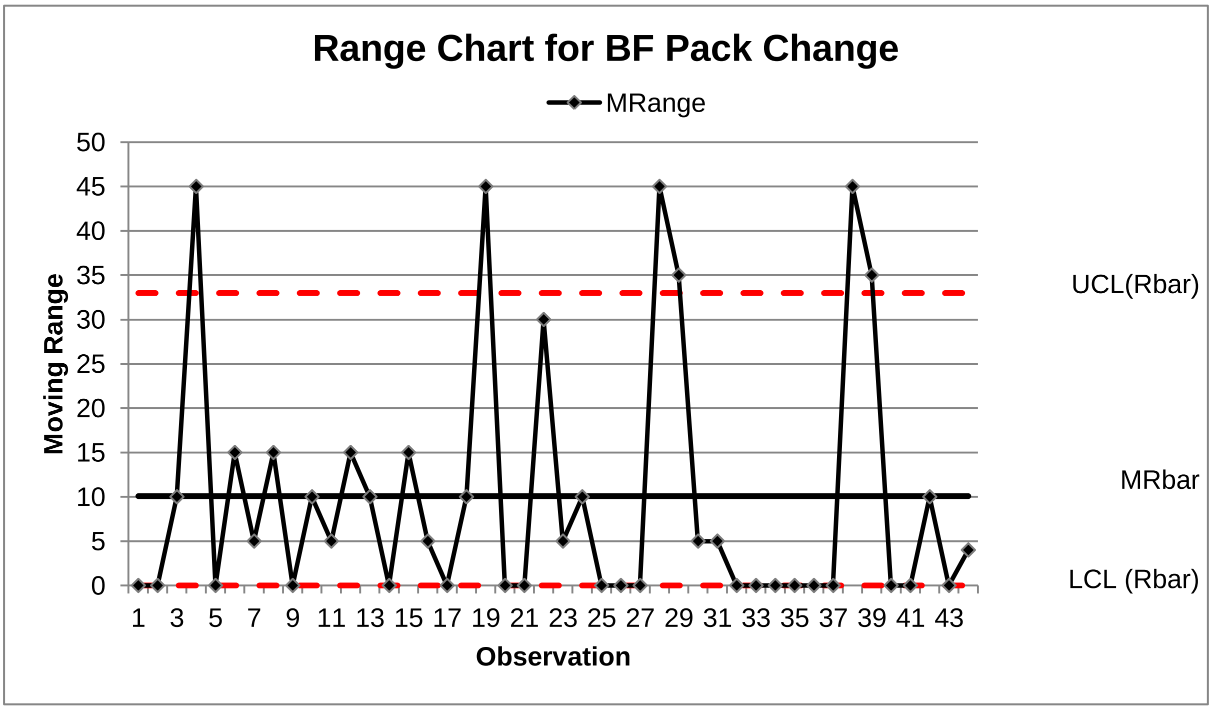
The first thing to notice from this analysis is the small amount of data points. The second observation is that the range chart shows no variation for most of the chart, but one can see on the Xbar chart the almost all the points were recorded as 15min. This can be due to the fact that the person capturing the data is using generic values and not the real values of the process. But with this said, the changeover between different brutal fruit flavours will probably be a very short changeover because only the neck label is different between flavours. This means that a brand change between brutal fruit flavours should be very quick.



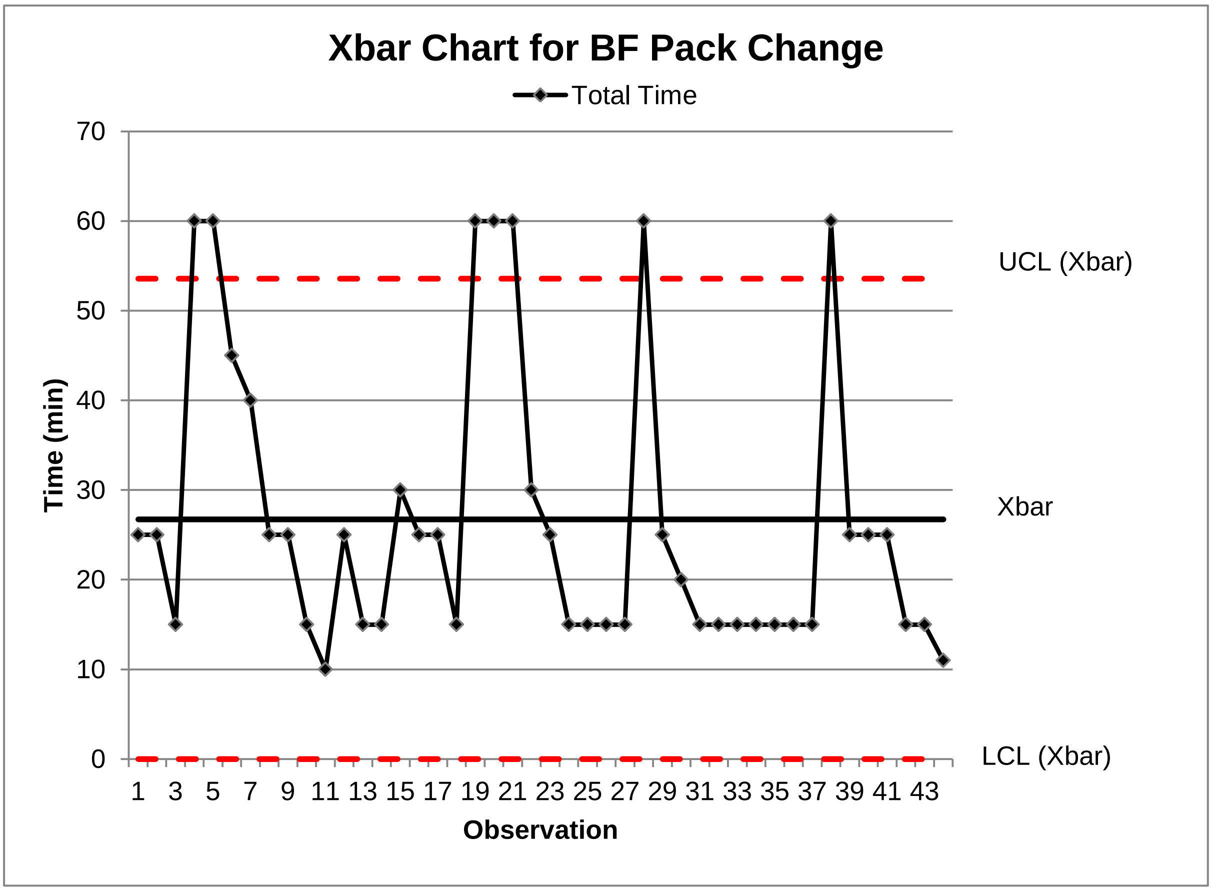
Graph 10: Xbar chart for Brutal Fruit brand change

3.2.1.2 Brutal fruit pack change

The data available for the brutal fruit pack changes did not state to which different brand and pack was changed, thus any combination could be possible. Some changeovers like Castle Lager Lite are known to be longer because of much more parts that need to be changed, thus the higher values may be to Castle Lager Lite but this cannot be said with certainty.



Graph 11: Range Chart for brutal Fruit Pack change



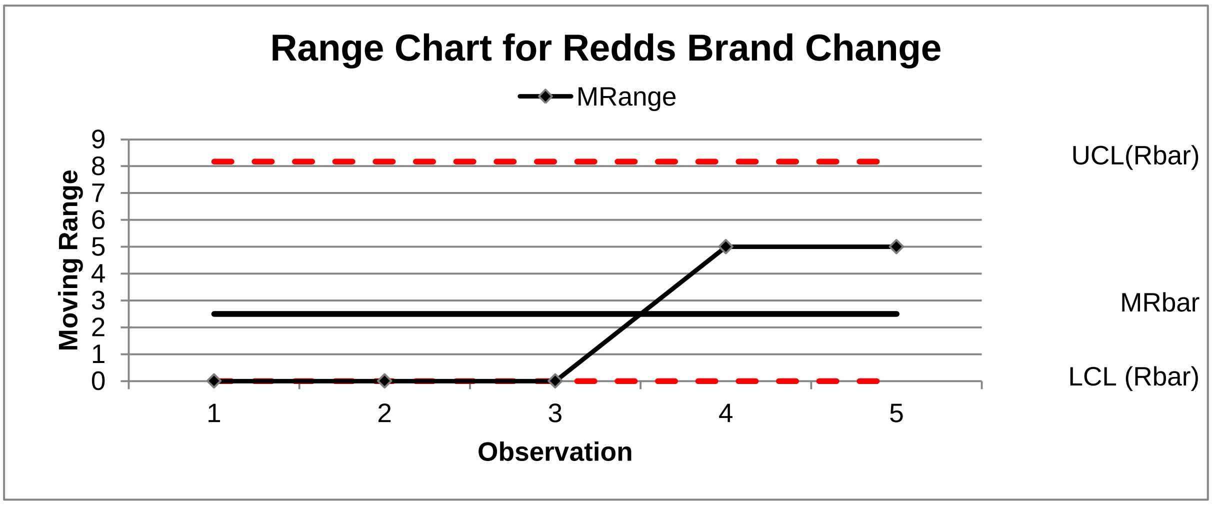
Graph 12: Xbar chart for Brutal Fruit pack change

The range chart for Brutal Fruit show an average of 10 which is quite high, but this can be explained because of the few outlier points in the graph. As previously mentioned this can be explained by changeovers to a brand like Castle Lager Lite.

The Xbar chart of Graph 12 shows that the average time for a pack change is 26.7min. There is however lower times recorded and this is the majority of the points. The lowest point is 10min which is a 16 min gap between the average times of a changeover. This chart clearly indicates two types of distributions that is recorded together and should be separated in a new data capturing system.

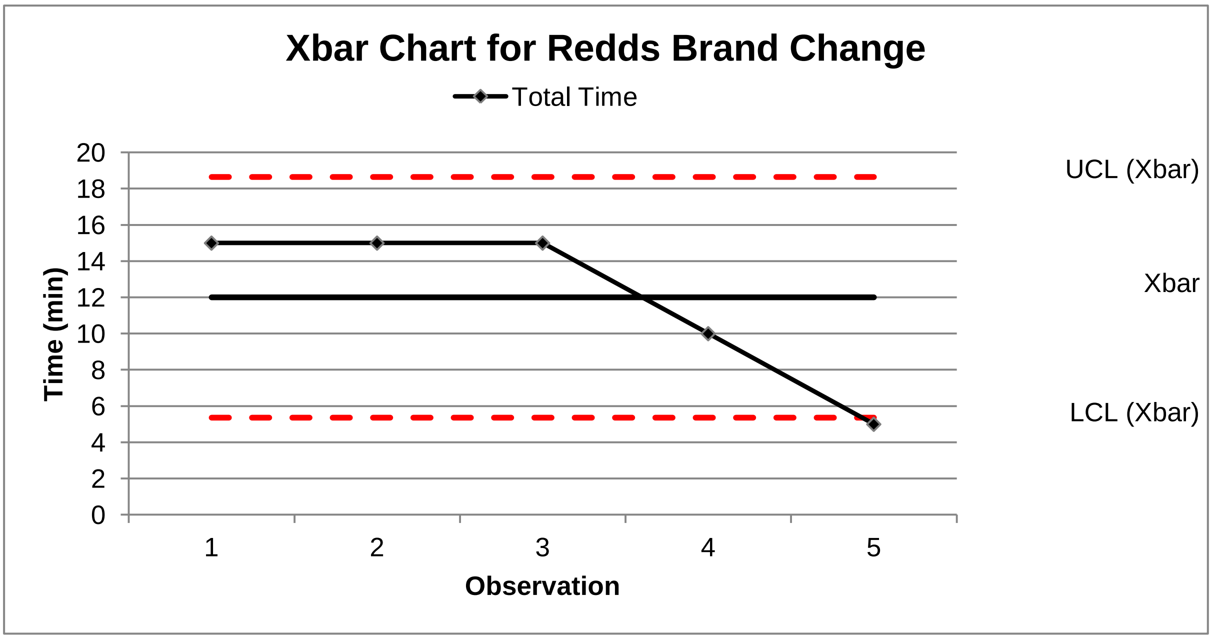
3.2.1.3 Redds brand change

The data points available for brand changes on Redds were very limited and therefore the charts below may not provide the best insight into brand changes of Redds. None the less, it is shown here and one can see as in the Brutal Fruit brand changes, the time of these changeovers is very short most of the time.



Graph 13: Range chart for Redds brand change

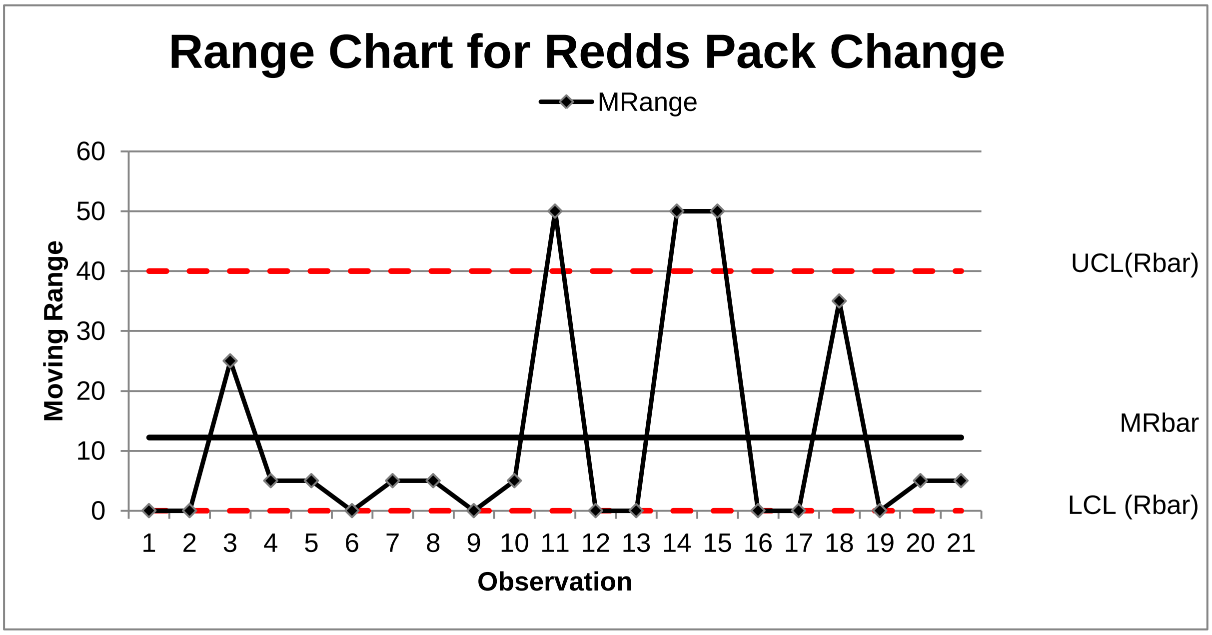
The 5min changeover at point 5 on the Xbar chart in Graph 14 is probably an incorrect data entry because a changeover cannot be conducted in 5min.



Graph 14: Xbar Chart for Redds change

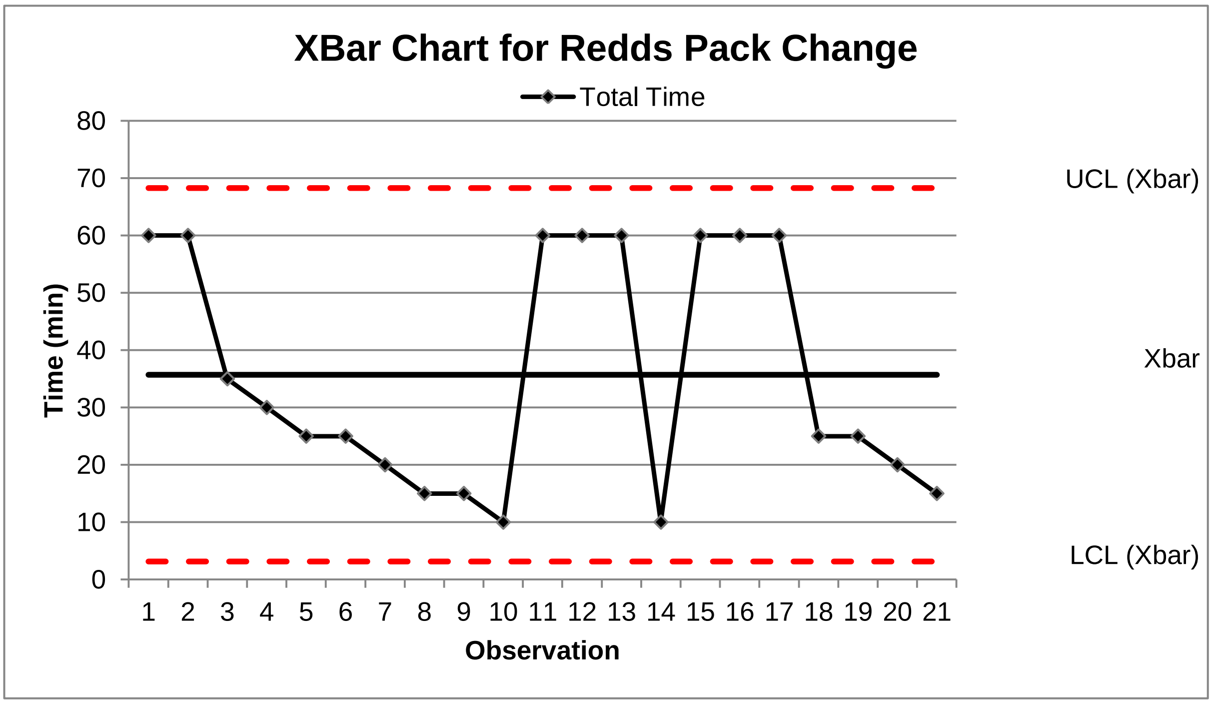
3.2.1.4 Redds pack change

The pack changes for Redds show only the times and no other detail, thus it is very hard to interpret the data to know why the changeovers takes longer and to what brand the changeover takes place.



Graph 15: Range chart for Redds pack change

The range chart for pack changes shown on Graph 15 on Redds have an average of 12.25, which is high, but once again, no detail was available to which brand was changed. The extreme points indicate that these specific brands are probably different than the rest and may take longer to change over. These outliers' results in a high average on the range chart.

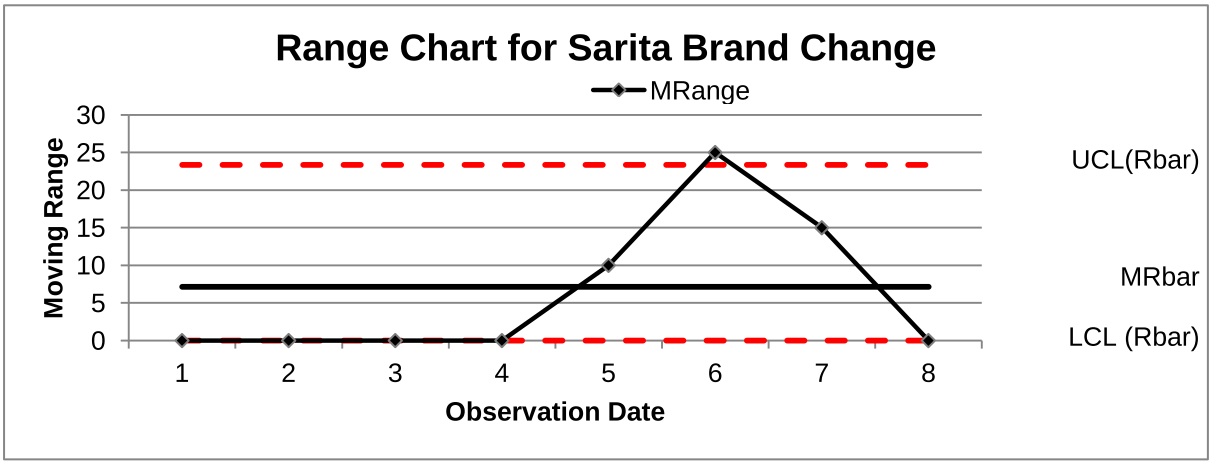


Graph 16: Xbar chart for Redds pack change

The Xbar chart of pack changes, Graph 16, for Redds show an average of 35.7min, but one can clearly see that average is influenced by the few outliers on 60min. Once again this is most likely to a pack change to Castle Lager Lite but this cannot be said with certainty.

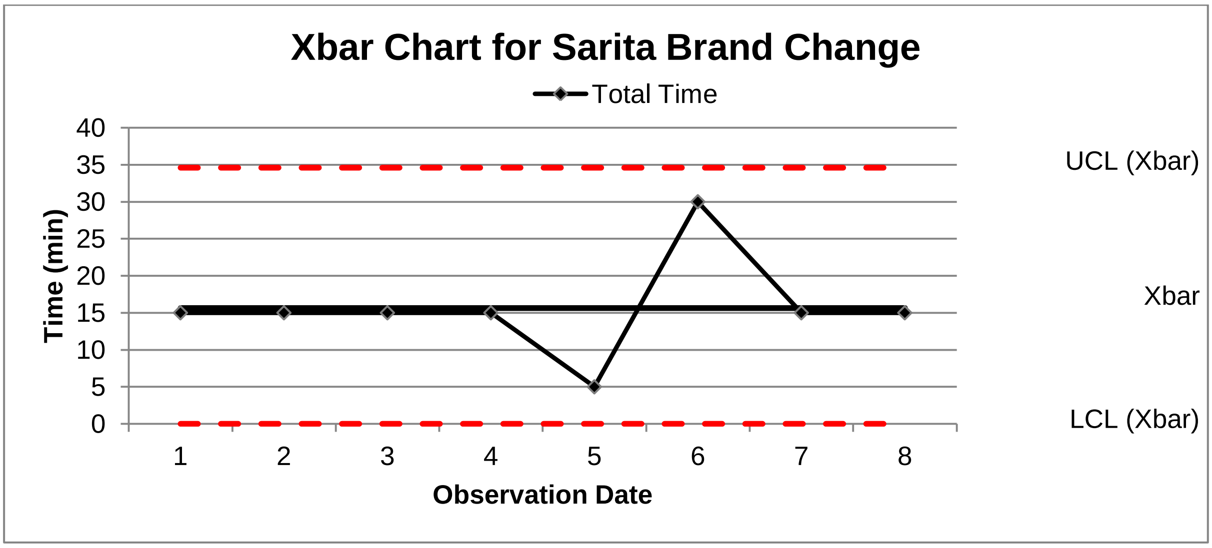
3.2.1.5 Sarita brand change

The brand change of Sarita also had limited data points to analyse and therefore it was difficult to interpret what the data is doing.



Graph 17: Range chart for Sarita brand change

From Graph 17 the moving range average is calculated as 7.1, but the outlier is difficult to explain, as it could be attributed to a problem encountered on that specific changeover or it could be a wrong data entry.

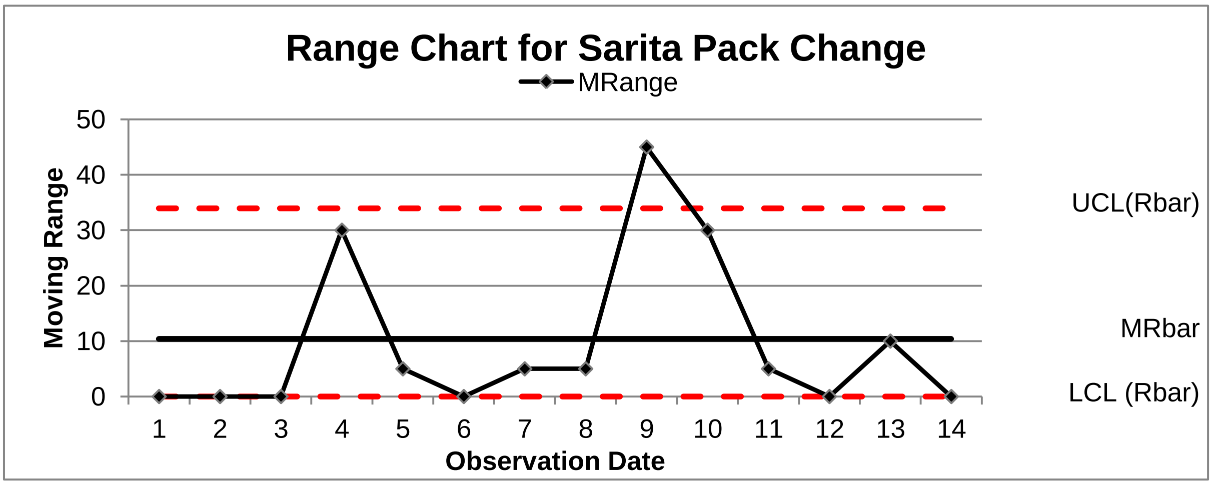


Graph 18: Xbar chart for Sarita Brand change

The Xbar chart shown in Graph 18 indicate and average of 15.6 min, but it can be clearly seen that most entries are recorded as 15 min, this means the person entering the data are using generic values and not recording the changeover times correctly. The low changeover time of 5min should also be an error, because changeovers cannot occur in 5min.

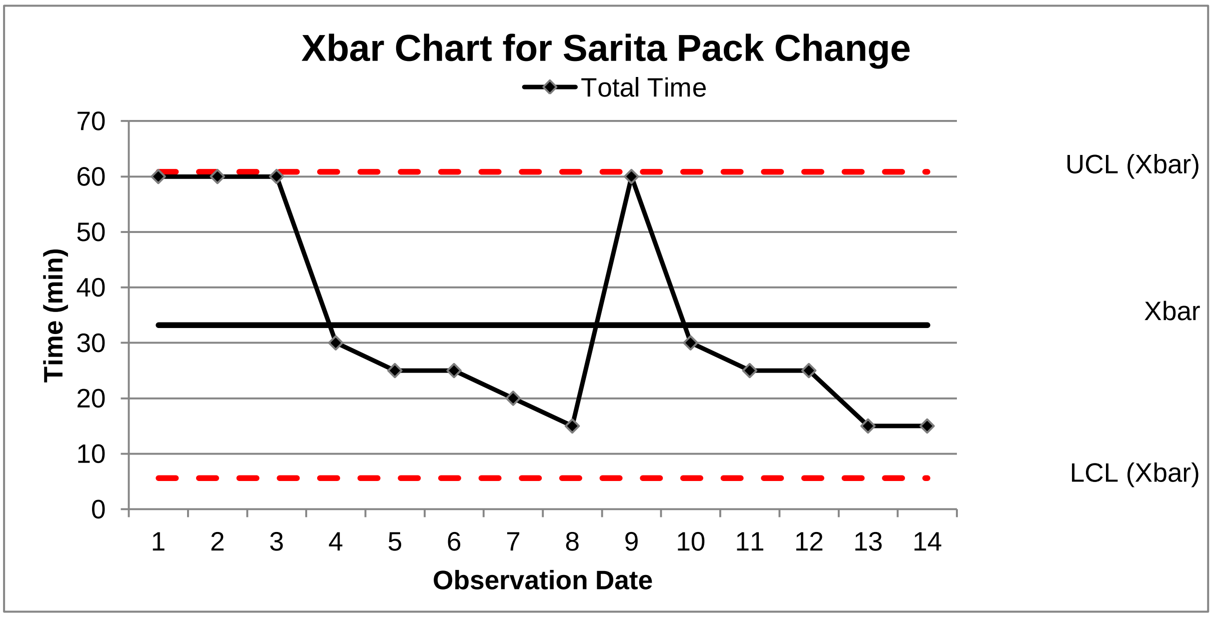
3.2.1.6 Sarita pack change

The pack changes for Sarita shows the same trend as the other two brands, with most of the values below 30min and only a few on 60 min. This may indicate that those long changeovers are changes to brands with many different parts or it may indicate a time that is entered into the system that is incorrect.



Graph 19: Range chart for Sarita Pack change

The range chart of Sarita pack changes shows a high average of 10, but this can be explained due to the fact of the high jumps between values on the Xbar chart, this causes the major values in the range chart.



Graph 20: Xbar chart for Sarita pack change

3.3 Target value estimation

There were two options available to choose the target values for improvement on the packaging line. The first option is to choose the best points on the charts and use the average of these points as the target value. This basically means to improve the process average to the previous best possible point. The other option is to calculate the target average, given that the threshold is the same as the process average plus 3 sigma variation. This is equivalent to setting the upper control limit to the threshold and calculating the desired average. The different values for these two options will be discussed below.

3.3.1 Inherent best of process

The inherent best of each process were calculated by taking a few of the lowest values and calculating the average for each different changeover. Table 3 shows the inherent best of each of these processes.

Change over Process	Time (min)
Brutal Fruit brand change	15
Redds brand change	13.75
Sarita brand change	15
Brutal fruit pack change	15
Redds pack change	21.25
Sarita pack change	20

Table 3: Inherent best times of each diffrent changeover process

3.3.2 Threshold as Upper control limit

By setting the threshold as the upper control limit and taking the Range average for each different changeover, the corresponding target average could be computed. Equation 1 was used for each different changeover calculation and the values are shown in Table 4 under the Xbar (min) column.

$$\bar{X} + 3\sigma = Threshold$$

$$\bar{X} + 3(\frac{\bar{R}}{d2}) = Threshold$$

$$\bar{X} + 3(\frac{\bar{R}}{1.128}) = Threshold$$

$$\boldsymbol{\bar{X} = Threshold - 3\left(\frac{\bar{R}}{1.128}\right)}$$

Equation 1: Xbar0 with threshold as UCL

Changeover Process	Threshold (min)	Rbar	Xbar (min)	Current performance (min)
Brutal fruit brand change	16.6	0.9	14.2	14.2
Redds brand change	18.6	2.5	11.9	12
Sarita brand change	34.6	7.1	15.8	15.6
Brutal fruit pack change	53.6	10	27	26.7
Redds pack change	68.3	12.5	35.1	35.71
Sarita pack change	60.8	10.4	33.1	33.2

Table 4: Xbar target values using the threshold as upper control limit and current changeover performance

It should be noted that the data provided does not shape an accurate picture of the current performance of the packaging line. Discussions with the line manager and team leaders point to values closer to 40min for brand changes and more than 60min for pack changes.

3.3.3 Final Target value

To calculate the target value for this line one approach could be followed. By taking the two possible target values of each brand and pack as discussed above (Inherent best and upper control limit as upper threshold) for each different changeover and computing the average of those two values, the resulting target values for each different changeover can be determined. Subtracting this new target from the current average or rather the average that the line manager and team leaders know gives the total savings in time. These calculated targets will be used as a goal for this project. These values are summarised in the Table 5.

The fact that the data is not very accurate needs to be taken into consideration when looking at the values in Table 5. In comparison to the averages of line 11 at Alrode, some of the values seem very unlikely. Therefore sound judgment needs to be used to make sure the target is not impossible.

Changeover Process	Current Average (min)	New Target Average (min)	Savings per changeover (min)
Brutal fruit brand change	30	15	15.28
Redds brand change	30	12.8	17.2
Sarita brand change	30	15	15
Brutal fruit pack change	60	26	34
Redds pack change	60	35	25
Sarita pack change	60	33	35

Table 5: New target values and savings for each changeover process

The line manager and team leaders have a good idea of the current performance of the line and estimates that a brand change could be done in less than 25 min and a pack change in less than 45 min. This also depends on the specific brand but is generally the same for all brands. They also agree that the current performance of a brand change is more or less 30min and the performance of a pack change is more than 60 min.

Thus the agreed targets are as follow:

Brand change target: **20 min**

Size change target: **40 min**

If these targets are achieved and the current performance of the line is more accurate to what the line manger thinks it is, then estimate savings for a brand change is calculated to be around 10min and that of pack change is estimated to be 20 min.

This is the optimistic view of what could be possible but usually a first run improvement effort will only yield maximum of 75% of those savings, therefore the realistic view would be 7min and 15 min savings for brand and pack changes respectively. The 75% targets are:

Brand change target: **23 min**

Size change target: **45 min**

3.3.4 Estimated cost savings

The value of saving is respectively 7min for brand changes and 15min for pack changes per changeover can be quantified to monetary value by taking the retail value of these products and multiplying it by the capacity of this line. This line has a capacity to produce 700 bottles per minute, and the average retail value of these products was taken to be R6.50 per bottle.

The retail value was calculated by looking at the average cost per bottle that could be bought at a wholesaler like Makro.

Therefore a saving of 7min equals R 31,850 per brand change and a 15min savings will yield R 68,250 per changeover for pack changes. This values need to be quantified to a weekly or monthly value that could possibly be saved. By looking at the given data and discussions with the line manager the average changeover performed per week were about 4 changeovers with a ratio of 70% brand changes and 30% pack changes. This amounts to about 3 brand changes and 1 pack change on average per week.

	Average Changeovers per week	**Savings per changeover**	**Savings Total**
Brand changes	3	R 31,850	R 95,550
Pack changes	1	R 68,250	R 68,250
Total savings per week			**R 163,800**

Table 6 : Estimated savings per week

From Table 6 it can be seen that a rough estimate can give you up R 160,000 of savings if the full 7min and 15min are reduced per changeover. This will probably not be the case during the initial improvements but substantial amount of money can be saved even if minor improvements are made.

3.4 Process map: low level

The low level process map was conducted to identify all the inputs and outputs that are present at each different process of the high level process map. An extract from one of the processes namely the depalletiser is shown in Table 7. The full low level process map is shown in appendix B. The goal of the low level process map is to use the inputs of each high level process and use it in the Cause and Effect (C/E) matrix to try and find the inputs that have the biggest impact on the changeover time.

All relevant inputs to the process are listed on the left column under inputs. The second column is to mark whether the input is controllable or uncontrollable (C/U). The process column lists the current process being examined (which is taken from the high level process map) and the final two columns list the outputs of that process as well as whether it is controllable or uncontrollable. This was done for each process namely the depalletiser, filler, pasteuriser, labeller 1 and 2, shrink-wrap machine, carton erector machine, tray packer, handle applicator and palletiser.

Inputs	C/U		Process		C/U	Outputs
Depal operator	**c**				**u**	Reusable wooden pallets
Forklift	**c**				**u**	Scrap pallets
Forklift driver	**c**				**u**	Reusable Divider cartons
Divider Cartons	**c**				**u**	Scrap Divider cartons
Confirm brand to be run with Filler operator	**c**				**u**	Old Brand bottles on line towards filler
Old Brand pallet with bottles	**c**				**u**	New Brand bottles on line towards filler
New Brand pallet with bottles	**c**	→	**Depalletiser**	→	**u**	Recorded counters(Depal)
Program on touch screen	**c**				**u**	CO time for Depal + Gap between bottles
Production Plan	**u**					
Team leader	**c**					
Counters	**u**					
Electrical Process artisan	**c**					
Mechanical process artisan	**c**					
Change over WI	**c**					

Table 7: Extract from the low level process map

Some of the outputs from each main process are inputs to the next process. These outputs are then carried over to the input of the next process. This is done for all outputs that are inputs into the next process. The outputs of the last process give an indication of the primary output of the entire process and the changeover time came out at the last process. It was carried through all of the processes till the end. This is just a confirmation that the main objective of this project, the reduction of changeover time, is a primary output of this whole process.

3.5 Cause and effect matrix

The cause and effect matrix is an adapted concept used by SAB which originated from the conventional cause and effect diagram or a fishbone diagram. This cause and effect matrix related more to a decision matrix than a cause and effect diagram. The cause and effect matrix was used to identify inputs which have the biggest effect on the changeover time. The inputs which had the biggest effect pointed out which process to focus on as well as on what aspect of that process.

The C/E matrix was conducted by assigning numerical values to each input which in turn indicated the effect that input has on the changeover time as well as quality of the product. A value of either 9 = High, 3 = Medium, 1 = Low or 0 = None was assigned and this value is multiplied by the outputs, which in this case was 10 = change over time and 5 = quality. These 2 multiplication sums are added up and a total value was assigned to each input. All the inputs were sorted from high to low according to the total score.

Discussions with operators and the team leaders were conducted to assign values to each input. An extract from the C/E matrix is shown below in Table 8 which indicates the inputs with the highest effect on changeover time. The full C/E matrix is shown in appendix C.

A common input that was constantly rated high on all the different machines was the operator. The operator seems to have a very big influence on the change over time, but this can be easily explained because the operators are the ones responsible for the changeover. Only in certain steps is a process artisan required, but this is minimal and most actions are performed by the operator themselves.

Also the two machines with the highest influence are the filler and labelling machines and greater focus will be placed on these machines and the changeover interactions regarding these machines. This C/E matrix confirms previous discussions with the unit manager that expected the filler and labeller machines as well as operators not performing the correct change over procedure to be the biggest factors affecting change over time.

		Importance rating to Customer	10	5	
		9	High	High	
		3	Medium	Medium	
		1	Low	Low	
		0	None	None	
C/U	**Process**	**Process Inputs**	**Primary Y = Change over time**	**Secondary Y = Product quality**	**Total**
c	**Palletiser and Stretch wrap**	Palletiser Operator	9	9	135
c	**Depalletiser**	Depal operator	9	9	135
c	**Rinser/Filler/Crowner**	Filler Operator	9	9	135
c	**Rinser/Filler/Crowner**	CIP (Cleaning) Program	9	9	135
c	**Rinser/Filler/Crowner**	Change over WI	9	9	135
c	**Pasteuriser**	Operator	9	9	135
u	**Labeller 1**	Pasteurised bottles, bad quality	9	9	135
c	**Labeller 1**	Labeller 1 Operator	9	9	135
c	**Labeller 1**	Cold Glue Aggregate station (Neck)	9	9	135
c	**Labeller 1**	Cold Glue Aggregate station (Body)	9	9	135
c	**Labeller 1**	Cold Glue Aggregate station (Back)	9	9	135
c	**Labeller 1**	Aggregate height settings (Neck, Body, Back)	9	9	135
c	**Labeller 1**	New Label trays	9	9	135
c	**Labeller 1**	New brushes	9	9	135
c	**Labeller 1**	Change over WI	9	9	135
u	**Labeller 2**	Pasteurised bottles, bad quality	9	9	135
c	**Labeller 2**	Labeller 2 Operator	9	9	135
c	**Labeller 2**	Cold Glue Aggregate station (Neck)	9	9	135
c	**Labeller 2**	Cold Glue Aggregate station	9	9	135

		(Body)			
c	**Labeller 2**	Cold Glue Aggregate station (Back)	9	9	135
c	**Labeller 2**	Aggregate height settings (Neck, Body, Back)	9	9	135
c	**Labeller 2**	New Label trays	9	9	135
c	**Labeller 2**	New brushes	9	9	135
c	**Labeller 2**	Change over WI	9	9	135
	Jones/Carton Erector	Jones Operator	9	9	135

Table 8: Cause and effect matrix extract

4. Analyze

The analysis phase consists of a failure mode and effect analysis (FMEA) and also a SMED analysis. The FMEA is a tool which identifies all the possible failures of each input from the C/E matrix and the effect of those failures on the output. The top rated inputs from the C/E matrix are used as an input for the FMEA from which to find possible solutions for each problem. The SMED analysis was conducted to identify the internal and external activities from the filler and labeller machines. This was done to see if any activities can be moved to external time or change internal activities.

4.1 SMED analysis

An analysis of the change over sequence of the filler and labeller machines was done to determine what activities can be done externally and which activities must be done internally. Table 9 describes the As-Is filler change over sequence, this table indicates the sequence for a full changeover including the changing of parts, therefore a pack change. A brand change will be similar but will skip the part removal and part fitting steps to indicate a result in a quicker changeover time.

Filler As-Is process					
Step	**Process**	**Task Description**	**Internal**	**External**	**Task time (min)**
1	Preparation	Check Cut off Volume		x	1
2	Preparation	Prepare de-pal cut of		x	
3	Preparation	Check and sign of FPT for readines1 hour before the cut-off		x	5
4	Preparation	Raw mat (Crown Prep)		x	5
5	Preparation	Get all cleaning equipment ready (HP guns brushes and Chemicals)		x	1
6	Preparation	Get the change part rack from the storage place and bring to the Filler area.		x	5
7	Preparation	Ensure that all the relevant tools are available list)		x	5
8	Preparation	Run out last bottles		x	4
9	Preparation	Check that all the bottle handling parts are ready and in place	x		2
10	Preparation	Select draining programme	x		1
11	Preparation	Put filler into basic position	x		1

12	Preparation	Stop bowl in the correct position.	x		1
13	Part Removal	Remove the star wheels and guides	x		2
14	Part Removal	In feed guides	x		2
15	Part Removal	Remove the scroll guide	x		2
16	Part Removal	Bottle Stop	x		2
17	Part Removal	Star wheels	x		2
18	Part Removal	Centre guides	x		2
19	Part Removal	Back Guide	x		2
20	Part Removal	Crowner Star Wheel	x		2
21	Part Removal	Discharge Guides	x		2
22	Part Removal	Close the doors	x		1
23	Part Removal	Re-set the machine	x		1
24	CIP	Hot flush	x		10
25	Crowner	Empty old product	x		5
26	Crowner	Insert New product	x		5
27	Crowner	Feed bottles to filler	x		2
28	Crowner	Checkmat change over	x		2
29	Part fitment	Crowner Star Wheel	x		2
30	Part fitment	Centre guides	x		2
31	Part fitment	Discharge Guides	x		2
32	Part fitment	In feed guides	x		2
33	Part fitment	Bottle Stop	x		2
34	Part fitment	Back Guide	x		2
35	Part fitment	Scroll guide	x		2
36	Part fitment	Star wheels	x		2
37	Start up	Change over the manifold for production	x		2
38	Start up	Return the filler to the basic mode.	x		1
40	Start up	Bring in Beer to Filler	x		5
41	Start up	Drain, Pressurise and blow off	x		10
42	Start up	Select production mode and confirm all settings (start up)	x		1
43	Start up	Start production	x		1
44	Post CO	Quality checks		x	10
45	Post CO	Cleaning of Change parts		x	15
46	Post CO	Storing of Change parts, Store the handling parts which belong together as a complete set and in their holders.		x	5
		Total	83	56	

Table 9: Filler As-Is SMED analysis

The total internal changeover time for the As-Is filler pack change is indicated as 83min. If a brand change is performed all the part removal steps are skipped, thus steps 13-23 and 28-36. The total changeover time of a brand change will then be 45 min.

By doing an analysis on this sequence by following the SMED steps it was found that only one activity could be externalised. Step 9 could be done externally. It was also found that if the filler operator is assisted by someone when changing the parts, the activity times could be reduced. The hot flush must also be performed between brands. The hot flush time is constant but cannot be excluded to external time because the filler doors must be closed for the hot flush to run.

The new To-Be sequence is shown in Table 10. The new pack changeover time should be 64min and the brand changeover should be 43min.

Filler To-Be process					
Step	**Process**	**Task Description**	**Internal**	**External**	**Task time (min)**
1	Preparation	Check Cut off Volume		x	1
2	Preparation	Prepare de-pal cut of		x	
3	Preparation	Check and sign of FPT for readines1 hour before the cut-off		x	5
4	Preparation	Raw mat (Crown Prep)		x	5
5	Preparation	Get all cleaning equipment ready(HP guns brushes and Chemicals)		x	1
6	Preparation	Get the change part rack from the storage place and bring to the Filler area.		x	5
8	Preparation	Ensure that all the relevant tools are available list)		x	5
9	Preparation	Run out last bottles		x	4
7	Preparation	Check that all the bottle handling parts are ready and in place		x	2
10	Preparation	Select draining programme	x		1
11	Preparation	Put filler into basic position	x		1
12	Preparation	Stop bowl in the correct position.	x		1
13	Part Removal	Remove the star wheels and guides	x		1
14	Part Removal	In feed guides	x		1
15	Part Removal	Remove the scroll guide	x		1
16	Part Removal	Bottle Stop	x		1
17	Part Removal	Star wheels	x		1
18	Part Removal	Centre guides	x		1
19	Part Removal	Back Guide	x		1
20	Part Removal	Crowner Star Wheel	x		1
21	Part Removal	Discharge Guides	x		1
22	Part Removal	close the doors	x		1
23	Part Removal	Re-set the machine	x		1
24	CIP	Hot flush	x		10
25	Crowner	Empty old product	x		5
26	Crowner	Insert New product	x		5
27	Crowner	Feed bottles to filler	x		2
28	Crowner	Checkmat change over	x		2
29	Part fitment	Crowner Star Wheel	x		1
30	Part fitment	Centre guides	x		1
31	Part fitment	Discharge Guides	x		1
32	Part fitment	In feed guides	x		1
33	Part fitment	Bottle Stop	x		1
34	Part fitment	Back Guide	x		1
35	Part fitment	Scroll guide	x		1
36	Part fitment	Star wheels	x		1
37	Start up	Change over the manifold for production	x		2
38	Start up	Return the filler to the basic mode.	x		1
40	Start up	Bring in Beer to Filler	x		5
41	Start up	Drain, Pressurise and blow off	x		10
42	Start up	Select production mode and confirm all settings (start up)	x		1
43	Start up	Start production	x		1
44	Post CO	Quality checks		x	10
45	Post CO	Cleaning of Change parts		x	15
46	Post CO	Storing of Change parts, Store the handling parts which belong together as a complete set and in their holders.		x	5
		Total	64	58	

Table 10: Filler To-Be SMED analysis

The As-Is analysis for the Labeller machines are shown in Table 11. From this analysis it can be seen that the pack changes for the labellers are quite long, but one thing to note is that a number of activities can be performed external. Most of the part removal and fitting can be done externally on an external aggregate which ideally are set up and plugged in to the labeller machine when a changeover must be performed.

Labeller As-Is					
Step	**Process**	**Task Description**	**Internal**	**External**	**Task time (min)**
1	Labeller	Check the production plan to confirm the product to be run and volume to be packed and ascertain cut-off time.		x	1
2	Labeller	Prepare labelling material		x	5
3	Labeller	Insert the follow line on the pasteuriser HMI		x	5
4	Labeller	Prepare and load labels for the old product to be run and ensure that there is sufficient glue available		x	3
5	Labeller	Clear the labeller reject tables		x	1
6	Labeller	Cut off line		x	2
7	Labeller	Run remaining bottles manually		x	2
8	Labeller	Stop/shutdown the machine for actual change over		x	2
9	Labeller	Check the change parts that are still in good condition(lubricated with no wear and tear)and all available, move change parts trolleys closer to the machine	x		3
10	Labeller	Disengage the aggregates from labeller and Set the distance between the bottle and the gripper cylinder (Neck, body, back)	x		6
11	Neck - Part removal	Label trays	x		0.5
12	Neck - Part removal	Tray slides	x		0.5
13	Neck - Part removal	Label follower	x		0.5
14	Neck - Part removal	Spacers	x		0.5
15	Neck - Part removal	Gripper cylinder	x		0.5
16	Neck - Part removal	Pallets	x		0.5
17	Neck - Part removal	Magazine	x		0.5
18	Neck - Part removal	Magazine guard	x		0.5
19	Body - Part removal	Label trays	x		0.5
20	Body - Part removal	Tray slides	x		0.5
21	Body - Part removal	Label follower	x		0.5
22	Body - Part removal	Spacers	x		0.5
23	Body - Part removal	Gripper cylinder	x		0.5
24	Body - Part removal	Pallets	x		0.5
25	Body - Part removal	Magazine	x		0.5
26	Body - Part removal	Magazine guard	x		0.5
27	Back - Part removal	Label trays	x		0.5
28	Back - Part removal	Tray slides	x		0.5
29	Back - Part removal	Label follower	x		0.5
30	Back - Part removal	Spacers	x		0.5
31	Back - Part removal	Gripper cylinder	x		0.5
32	Back - Part removal	Pallets	x		0.5
33	Back - Part removal	Magazine	x		0.5
34	Back - Part removal	Magazine guard	x		0.5
35	Part removal	Star wheels, guides and in feed worm	x		6
36	Part fitment	Star wheels, guides and in feed worm	x		6
37	Neck - Part fitment	Label trays	x		0.5
38	Neck - Part fitment	Tray slides	x		0.5

39	Neck - Part fitment	Label follower	x		0.5
40	Neck - Part fitment	Spacers	x		0.5
41	Neck - Part fitment	Gripper cylinder	x		0.5
42	Neck - Part fitment	Pallets	x		0.5
43	Neck - Part fitment	Magazine	x		0.5
44	Neck - Part fitment	Magazine guard	x		0.5
45	Body - Part fitment	Label trays	x		0.5
46	Body - Part fitment	Tray slides	x		0.5
47	Body - Part fitment	Label follower	x		0.5
48	Body - Part fitment	Spacers	x		0.5
49	Body - Part fitment	Gripper cylinder	x		0.5
50	Body - Part fitment	Pallets	x		0.5
51	Body - Part fitment	Magazine	x		0.5
52	Body - Part fitment	Magazine guard	x		0.5
53	Back - Part fitment	Label trays	x		0.5
54	Back - Part fitment	Tray slides	x		0.5
55	Back - Part fitment	Label follower	x		0.5
56	Back - Part fitment	Spacers	x		0.5
57	Back - Part fitment	Gripper cylinder	x		0.5
58	Back - Part fitment	Pallets	x		0.5
59	Back - Part fitment	Magazine	x		0.5
60	Back - Part fitment	Magazine guard	x		0.5
61	Part removal	Brushes, rollers, wipe down pads, centring bells	x		5
62	Part fitment	Brushes, rollers, wipe down pads, centring bells	x		5
63	Adjustment	Set the brand on the Touch Screen	x		1
64	Adjustment	Set inspection camera's	x		1
65	Adjustment	Set fill height inspection for brand to be run	x		1
66	Adjustment	Set taptone for brand to be run	x		1
67	Adjustment	Set aggregate distance between the bottle and aggregate	x		1
68	Adjustment	Set aggregate station neck height	x		1
69	Adjustment	Set aggregate station body height	x		1
70	Adjustment	Set aggregate station back height	x		1
71	Adjustment	Set glide liner to correct bottle type(for pack change)	x		2
72	Adjustment	Ensure video jet on	x		1
73	Adjustment	Adjust the conveyors as per bottle size to be run	x		2
74	Labeller	Start machine	x		1
75	Labeller	Run the test bottles	x		5
76	Labeller	Review checklist at Labeller	x		1
77	Labeller	Machine started for full run	x		1
78	Labeller	The quality at full speed meets specification	x		4
79	Labeller	Clean and store the parts in the Trolley Parts (gripper cylinder is kept on machine)		x	
80	Labeller	Return the change parts trolleys and A frames to the designated areas		x	1
		Total	77	22	

Table 11: Labeller As-Is SMED analysis

The To-Be analysis shows a significant decrease in changeover time of pack changes. This is due to the fact that the part removal can be done on an external aggregate which holds all the parts. Table 12 shows the To-Be SMED analysis which brings the total internal changeover time from 77min to 53min.

Labeller To-Be					
Step	**Process**	**Task Description**	**Internal**	**External**	**Task time (min)**
1	Labeller	Check the production plan to confirm the product to be run and volume to be packed and ascertain cut-off time.		x	1
2	Labeller	Prepare labelling material		x	5
3	Labeller	Insert the follow line on the pasteuriser HMI		x	5
4	Labeller	Prepare and load labels for the old product to be run and ensure that there is sufficient glue available		x	3
5	Labeller	Clear the labeller reject tables		x	1
6	Labeller	Cut off line		x	2
7	Labeller	Run remaining bottles manually		x	2
8	Labeller	Stop/shutdown the machine for actual change over		x	2
9	Labeller	Check the change parts that are still in good condition(lubricated with no wear and tear)and all available, move change parts trolleys closer to the machine		x	3
10	Labeller	Disengage the aggregates from labeller and Set the distance between the bottle and the gripper cylinder (Neck, body, back)	x		6
11	Neck - Part removal	Label trays		x	0.5
12	Neck - Part removal	Tray slides		x	0.5
13	Neck - Part removal	Label follower		x	0.5
14	Neck - Part removal	Spacers		x	0.5
15	Neck - Part removal	Gripper cylinder		x	0.5
16	Neck - Part removal	Pallets		x	0.5
17	Neck - Part removal	Magazine		x	0.5
18	Neck - Part removal	Magazine guard		x	0.5
19	Body - Part removal	Label trays		x	0.5
20	Body - Part removal	Tray slides		x	0.5
21	Body - Part removal	Label follower		x	0.5
22	Body - Part removal	Spacers		x	0.5
23	Body - Part removal	Gripper cylinder		x	0.5
24	Body - Part removal	Pallets		x	0.5
25	Body - Part removal	Magazine		x	0.5
26	Body - Part removal	Magazine guard		x	0.5
27	Back - Part removal	Label trays		x	0.5
28	Back - Part removal	Tray slides		x	0.5
29	Back - Part removal	Label follower		x	0.5
30	Back - Part removal	Spacers		x	0.5
31	Back - Part removal	Gripper cylinder		x	0.5
32	Back - Part removal	Pallets		x	0.5
33	Back - Part removal	Magazine		x	0.5
34	Back - Part removal	Magazine guard		x	0.5
35	Part removal	Star wheels, guides and in feed worm	x		6
36	Part fitment	Star wheels, guides and in feed worm	x		6
37	Neck - Part fitment	Label trays		x	0.5
38	Neck - Part fitment	Tray slides		x	0.5
39	Neck - Part fitment	Label follower		x	0.5
40	Neck - Part fitment	Spacers		x	0.5
41	Neck - Part fitment	Gripper cylinder		x	0.5
42	Neck - Part fitment	Pallets		x	0.5
43	Neck - Part fitment	Magazine		x	0.5
44	Neck - Part fitment	Magazine guard		x	0.5
45	Body - Part fitment	Label trays		x	0.5
46	Body - Part fitment	Tray slides		x	0.5
47	Body - Part fitment	Label follower		x	0.5
48	Body - Part fitment	Spacers		x	0.5

49	Body - Part fitment	Gripper cylinder		x	0.5
50	Body - Part fitment	Pallets		x	0.5
51	Body - Part fitment	Magazine		x	0.5
52	Body - Part fitment	Magazine guard		x	0.5
53	Back - Part fitment	Label trays		x	0.5
54	Back - Part fitment	Tray slides		x	0.5
55	Back - Part fitment	Label follower		x	0.5
56	Back - Part fitment	Spacers		x	0.5
57	Back - Part fitment	Gripper cylinder		x	0.5
58	Back - Part fitment	Pallets		x	0.5
59	Back - Part fitment	Magazine		x	0.5
60	Back - Part fitment	Magazine guard		x	0.5
61	Part removal	Brushes, rollers, wipe down pads, centring bells	x		5
62	Part fitment	Brushes, rollers, wipe down pads, centring bells	x		5
63	Adjustment	Set the brand on the Touch Screen	x		1
64	Adjustment	Set inspection camera's	x		1
65	Adjustment	Set fill height inspection for brand to be run	x		1
66	Adjustment	Set taptone for brand to be run	x		1
67	Adjustment	Set aggregate distance between the bottle and aggregate	x		1
68	Adjustment	Set aggregate station neck height	x		1
69	Adjustment	Set aggregate station body height	x		1
70	Adjustment	Set aggregate station back height	x		1
71	Adjustment	Set glide liner to correct bottle type(for pack change)	x		2
72	Adjustment	Ensure video jet on	x		1
73	Adjustment	Adjust the conveyors as per bottle size to be run	x		2
74	Labeller	Start machine	x		1
75	Labeller	Run the test bottles	x		5
76	Labeller	Review checklist at Labeller	x		1
77	Labeller	Machine started for full run	x		1
78	Labeller	The quality at full speed meets specification	x		4
79	Labeller	Clean and store the parts in the Trolley Parts (gripper cylinder is kept on machine)		x	
80	Labeller	Return the change parts trolleys and A frames to the designated areas		x	1
		Total	53	49	

Table 12: Labeller To-Be SMED analysis

By observing the process some other problems could easily be noticed. One of the biggest problems that were observed during changeovers was the change parts management. This was common to both the labellers and filler because the filler and labellers have the most amounts of parts to change. The problem with the change part management is that parts are not clearly marked and some parts are missing. This leads to parts that are incorrect during changeovers and the operator starts searching for the correct part. This is an activity that should be entirely eliminated. The change parts room where all the A-frame trolleys with change parts are stored are also disorganised. This causes confusion and sometimes the incorrect trolleys are taken which wastes time.

During changeovers it was also observed that the labellers do the changeover at the same time. This is inefficient because one labeller should be cut off and the changeover must be performed on that labeller while the other labeller continues production of the old brand to run the remaining bottles out. This can easily be fixed by managing the changeover correctly to ensure that the labellers don't change at the same time.

4.2 Failure mode and effect analysis

The primary objective of a Failure Mode and Effect Analysis (FMEA) is to identify the ways how a product or process inputs can fail and the effect of such a failure on the process outputs. In this sense the FMEA will help to identify what can go wrong and what impact such a failure can have on the changeover time of this packaging line.

FMEA is a structured approach using the top rated inputs from the C/E matrix as input to the FMEA. Each input's risk and associated causes are evaluated and prioritised to ensure the correct action is taken to prevent these failures. Possible solutions to each problem are listed and expanded upon in the improvement plan.

Table 14 shows the data gathered for the FMEA and sorted the inputs form largest to smallest according to the Risk Priority Number (RPN). The RPN is calculated by multiplying the severity (SEV), occurrence (OCC) and detection (DET) values. Each of these values can take a number from 1-10 according to the scale shown in Table 13. The detection scale is opposite from the severity and occurrence scale, because a high detection number will mean a high chance of the failure to not be detected.

Value	Severity (SEV)	Occurrence (OCC)	Detection (DET)
1	No effect on CO time	Never occurs	Certain detection
2	Very Minor effect on CO time	Low occurrence	Almost certain of detection
3	Minor effect on CO time	Low occurrence	Low chance of not detection
4	Moderate effect on CO time	Moderate occurrence	Moderate chance of not detecting
5	Moderate effect on CO time	Moderate occurrence	Moderate chance of not detecting
6	Moderate effect on CO time	Moderate occurrence	Moderate chance of not detecting
7	High impact on CO time	High occurrence	High chance of not detecting
8	High impact on CO time	High occurrence	High chance of not detecting
9	Drastically increase CO time	Occurs every changeover on a machine	Unable to detect
10	Drastically increase CO time	Occurs every changeover on most machines	Unable to detect

Table 13: FMEA scale

The highest rated process inputs of the FMEA indicate a big problem with parts not being marked clearly and changeover trolleys not organised correctly. This confirms the suggestion that a lot of time is wasted searching for parts. Even though trolleys are clearly marked where parts should be stored, it is usually not placed on the correct position and when the next changeover occurs the parts are mixed up and sometimes not even on the correct trolley.

Process Step	Key Process Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
What is the process step	What is the Key Process Input?	In what ways can the Key Input increase CO time/can be influenced to reduce CO time?	What is the impact on the CO time or internal requirements?	How Severe is the effect?	What causes the Key Input to add CO time?	How often does cause occur?	What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode?	How well can you detect cause?		What are the actions for reducing the occurrence of the Cause, or improving detection?
Rinser/Filler /Crowner	New Change parts trolley	Incorrect change parts on trolley	Change over time increase	**10**	Change parts management	**4**	Change part/QCT technician looking after and preparing change parts	**4**	**160**	Part markings, CO part management
Labeller	New Change parts trolley	Incorrect change parts on trolley	Change over time increase	**10**	Change parts management	**4**	Change part/QCT technician looking after and preparing change parts	**4**	**160**	Part markings, CO part management
Rinser/Filler /Crowner	Filler Operator	Incorrect change parts installed	Increase/Decrease CO time	**10**	Lack of training or coaching	**3**	Change parts identified per pack size and marked	**3**	**90**	Change part trolley must be organised, parts marked to facilitate easy installation
Labeller	Labeller 1 Operator	Incorrect change parts installed	Increase/Decrease CO time	**10**	Lack of training or coaching	**3**	Change parts identified per pack size and marked	**3**	**90**	Change part trolley must be organised, parts marked to facilitate easy installation
Rinser/Filler /Crowner	New Rinser star wheels	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Rinser/Filler /Crowner	New Filler star wheels	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Rinser/Filler /Crowner	New Crowner star wheels	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Rinser/Filler /Crowner	New In feed worm	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Rinser/Filler /Crowner	New Guides	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Rinser/Filler /Crowner	Change over WI	Incorrect or outdated	Incorrect CO procedure causing increase in CO time	**10**	Incorrect procedures for changing parts	**3**	All WI reviewed bi annually and change if required	**2**	**60**	Update WI to current brands produced by the packing line

Labeller	New Label trays	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New Tray slides	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New label follower	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New spacers	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New Wipe down brushes	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New star wheels	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New guides	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New in feed worm	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New centring bells	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New bottle plates	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	New brushes	Damage to parts	Repair change parts/Replace parts and increase CO time	**10**	Incorrect change parts handling	**2**	Maintenance checks as per maintenance best practice	**3**	**60**	Check maintenance log before changeover and check parts for damage
Labeller	Change over WI	Incorrect or outdated	Incorrect CO procedure causing increase in CO time	**10**	Incorrect procedures for changing parts	**3**	All WI reviewed bi annually and change if required	**2**	**60**	Update WI to current brands produced by the packing line

Rinser/Filler /Crowner	Old Change parts trolley	Incorrect change parts on trolley	Change over time increase	**3**	Change parts management	**3**	Change part/QCT technician looking after and preparing change parts	**6**	**54**	Part markings, CO part management
Labeller	Old Change parts trolley	Incorrect change parts on trolley	Change over time increase	**3**	Change parts management	**3**	Change part/QCT technician looking after and preparing change parts	**6**	**54**	Part markings, CO part management
Rinser/Filler /Crowner	Team leader	Communication for new brand in pre shift meeting	Unprepared changeover/Increa se COT	**5**	Delay in preparation for changeover	**1**	Pre shift meetings/Production plan communications	**8**	**40**	No action
Labeller	Team leader	Communication for new brand in pre shift meeting	Unprepared changeover/Increa se COT	**5**	Delay in preparation for changeover	**1**	Pre shift meetings/Production plan communications	**8**	**40**	No action
Rinser/Filler /Crowner	CIP (Cleaning) Program	CIP Program failure/Delay in start of CIP	Delay to Changeover or machine setup	**8**	Valve failure/Temperatur e/NaOH conductivity	**2**	Visual Scada/Set points in PLC programme	**2**	**32**	Check maintenance log before changeover and check parts for damage
Labeller	PSL Aggregate station (Neck)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep
Labeller	PSL Aggregate station (Body)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep
Labeller	PSL Aggregate station (Back)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep
Labeller	Cold Glue Aggregate station (Neck)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep
Labeller	Cold Glue Aggregate station (Body)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep
Labeller	Cold Glue Aggregate station (Back)	External preparation not done externally	CO/ time increases	**10**	CO preparation not done correctly/ Operator incapacity	**2**	No checks in place	**1**	**20**	Team leader should check external prep

Table 14: FMEA

5. Improvement Plan

The scope of this project only involved suggestions of possible improvements to the process. Because this is an undergraduate project and only part time attention was available to complete the project the improvement plan implementation is given responsibility to the process owner or line manager to decide whether the suggestions will be implemented and to lead such an improvement plan.

Because this specific packaging line is very new in comparison to other packaging lines, some of the physical processes regarding changeovers have been already optimized in the design of this line, meaning quick release mechanisms is used on all machines to assemble and disassemble parts from the machine. Therefore physical changes to the machines to improve changeover time are very limited at the moment. Rather a lot of improvements can be made by correct time management, better management of changeovers and performance evaluation and recording. Three suggestions will be discussed in detail as well as the impact of the solutions.

5.1 Change part management solution

The change part management solution addresses several problems under one solution. The problems that will be addressed include: Changeover parts not clearly marked, Changeover trolleys not clearly marked and managed during changeovers. The impact of having an effective change parts management system can greatly increase the change over time, due to the fact that much of the time is wasted due to searching for parts that is on the incorrect trolley or either missing totally.

A solution to solve the parts not being marked can be resolved by fixing a metal plate with the part number engraved as well as for what brand this part is to each specific part. The metal plate will be durable to withstand any wear and tear and would probably not need to be replaced before the part wears out. The sequence number for how the part should be installed should also be engraved to ensure easier installation. Coloured stickers for each different brand should also be applied to the parts because each brand is already assigned a colour on the production system. This may aid in ensuring the correct brand parts are installed. Figure 3 and Figure 4 show examples of the parts and the suggested metal plates.

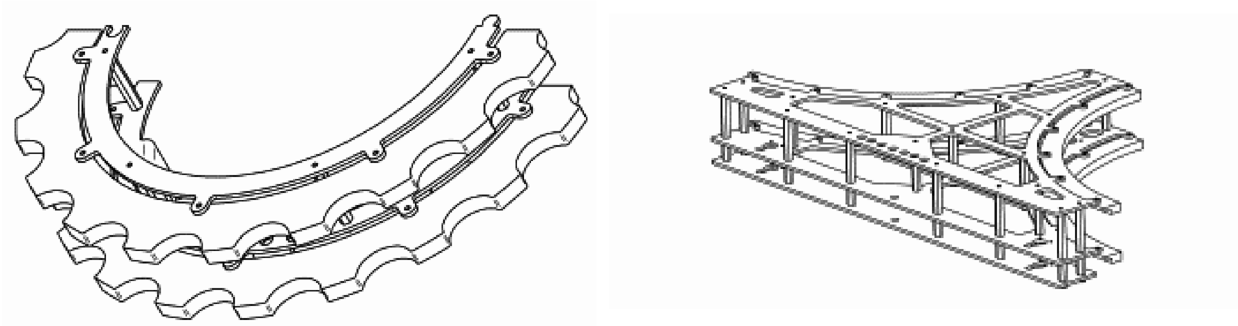


Figure 3: Example of a change part of filler (SAB internal 2009)

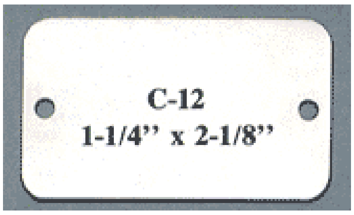


Figure 4: Metal plate example

A system to ensure change parts are checked and brought to the machines before the changeover should also be implemented. A simple check sheet with all the needed parts for the specific brand should be completed and signed by the operator and changeover specialist. This will ensure that the correct parts are ready and available when the changeover commences.

Figure 5 illustrate the suggested process to follow as part of the change part management system. This figure shows that the CO specialist needs to check which brands are going to be changed over and needs to prepare the new CO parts, this includes checking parts for unexpected wear, damage or even theft. The CO specialist then hands over the parts to the operator which signs that he received all parts correctly, thus the operator needs to quickly check that all parts needed are present. These activities are all done externally long before the internal changeover starts.

When the internal changeover starts the operator needs to log his time and when the internal changeover is completed he must log his time again. The team leader will then collect these times and input the data into the data tracker spreadsheet.

1. •CO spesialist checks the brands and packs of next changeover
2. •Operater recieves and check for correct new CO parts (signs checksheet)
3. •Operator records start time of internal CO
4. •Operator records end time of internal CO
5. •Operator hands over old CO parts (CO speacilist signs checksheet)
6. •Teamleader collects recorded CO times from operator
7. •Teamleader inputs CO data into spreadsheet

Figure 5: Suggested CO activities for correct part management

An example of a possible sheet that could be used for this process is shown in Figure 6. This will facilitate easy control and auditing if problems occur. The operator will also need to record the changeover time to ensure that accurate data capturing will take place as seen on the example check sheet.

Chamdor line 7 CO Check sheet

Date:

Changing from: ______________ to: ______________ Brand/Pack changeover

New parts trolley

	Yes	No
Have all parts been received?		
Are all parts in a working condition for use in changeover		

Operator signature: ______________

Old parts trolley

	Yes	No
Are trolley free of any foreign parts?		

Operator signature: ______________

CO time recording

CO internal start time: ______________

CO internal stop time: ______________

Operator signature: ______________

CO specialist signature: ______________

Team leader signature: ______________

Figure 6: Change over check sheet

5.2 Data capturing and performance assessment system

One of the biggest problems concerning this packaging line is that data related to change over time was either not being recorder or the data was recorded into the system using generic times of fake times. Thus there is no value in the current system to track the progress and performance of changeovers and no improvement attempts can succeed if performance of the line is not accurately tracked.

A simple system regarding operators recording the changeovers and team leaders checking the times and then transferring these times recorded on paper to an Excel spreadsheet for further analysis can be implemented as part of the daily production data that must be filled in by the operators.

The Excel spreadsheet has been developed to ensure easy data capturing that will automatically draw graphs for the line manager to analyze monthly or weekly. A screenshot of the basic data capturing sheet is shown in Figure 7.

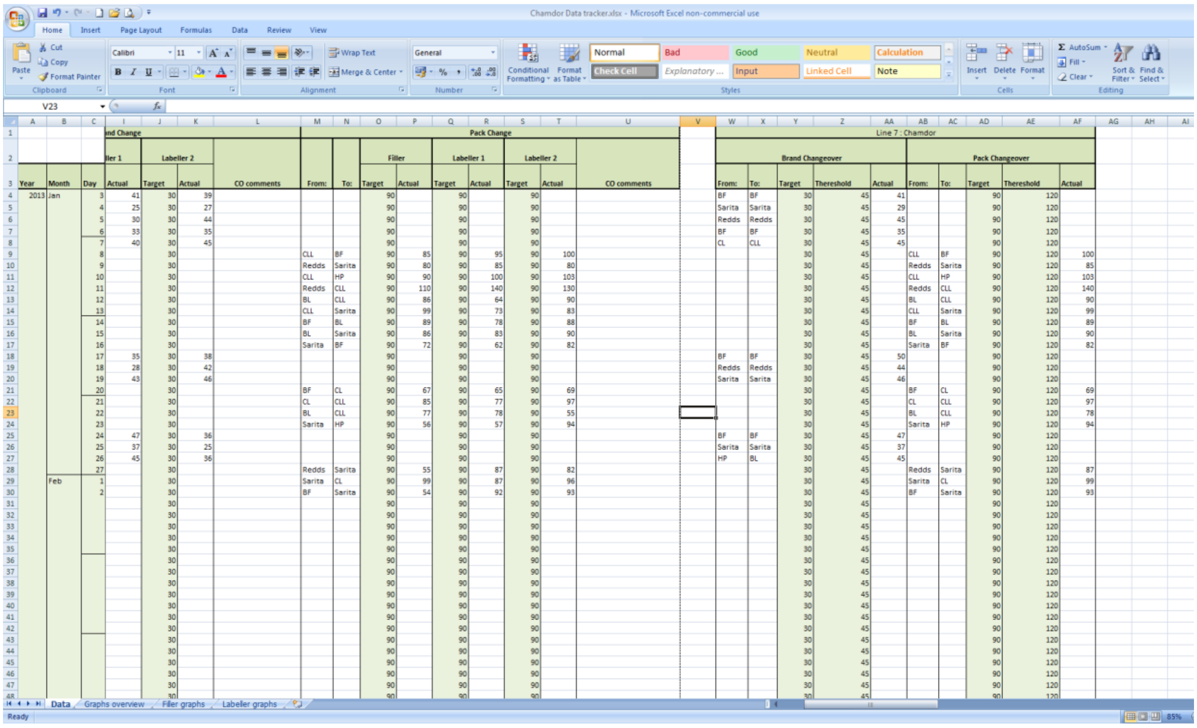


Figure 7: Screen capture of the data tracker spreadsheet

The graphs are automatically drawn from the data and help to achieve easier data analysis. A screenshot of the graphs are shown in Figure 8 and Figure 9. Graphs that are drawn include the Brand and Pack average CO time, and also for each individual machine which includes the filler, labeller 1 and labeller 2. The moving range charts are also drawn for each of the Xbar charts mentioned.

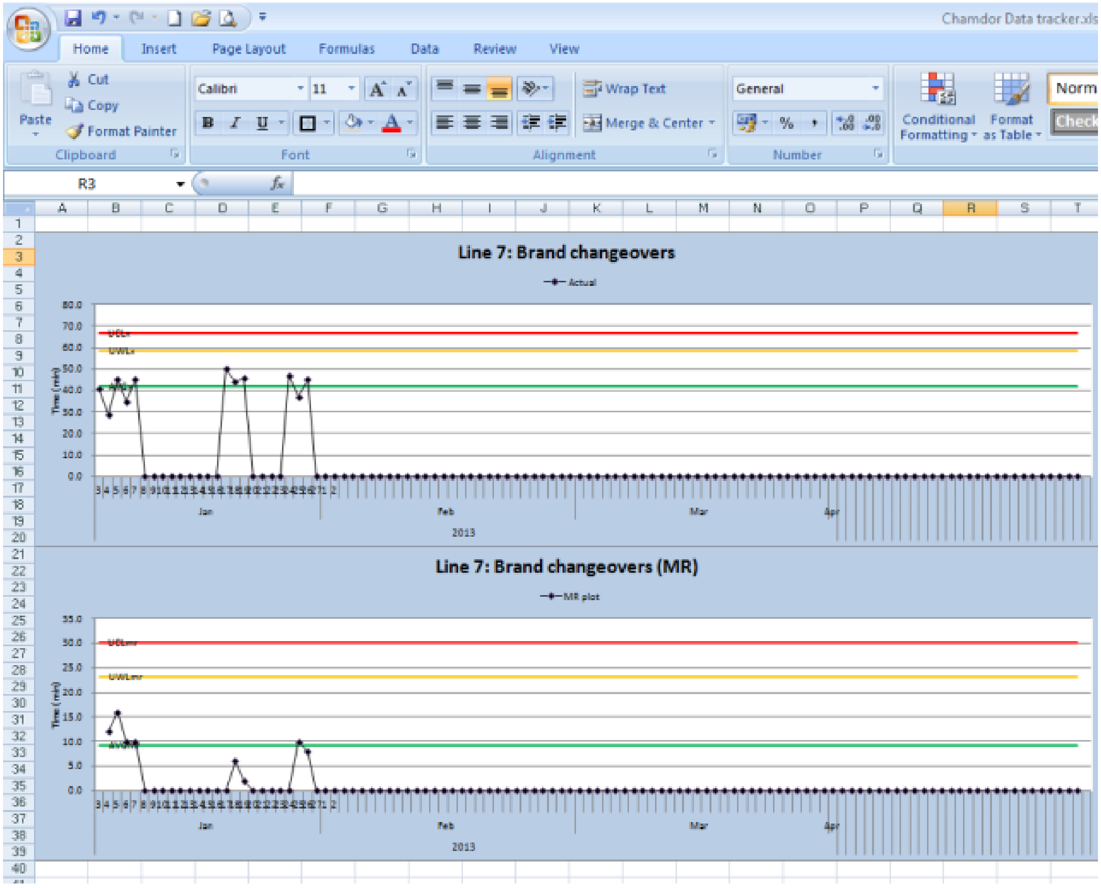


Figure 8: Screen capture of brand changeover graphs

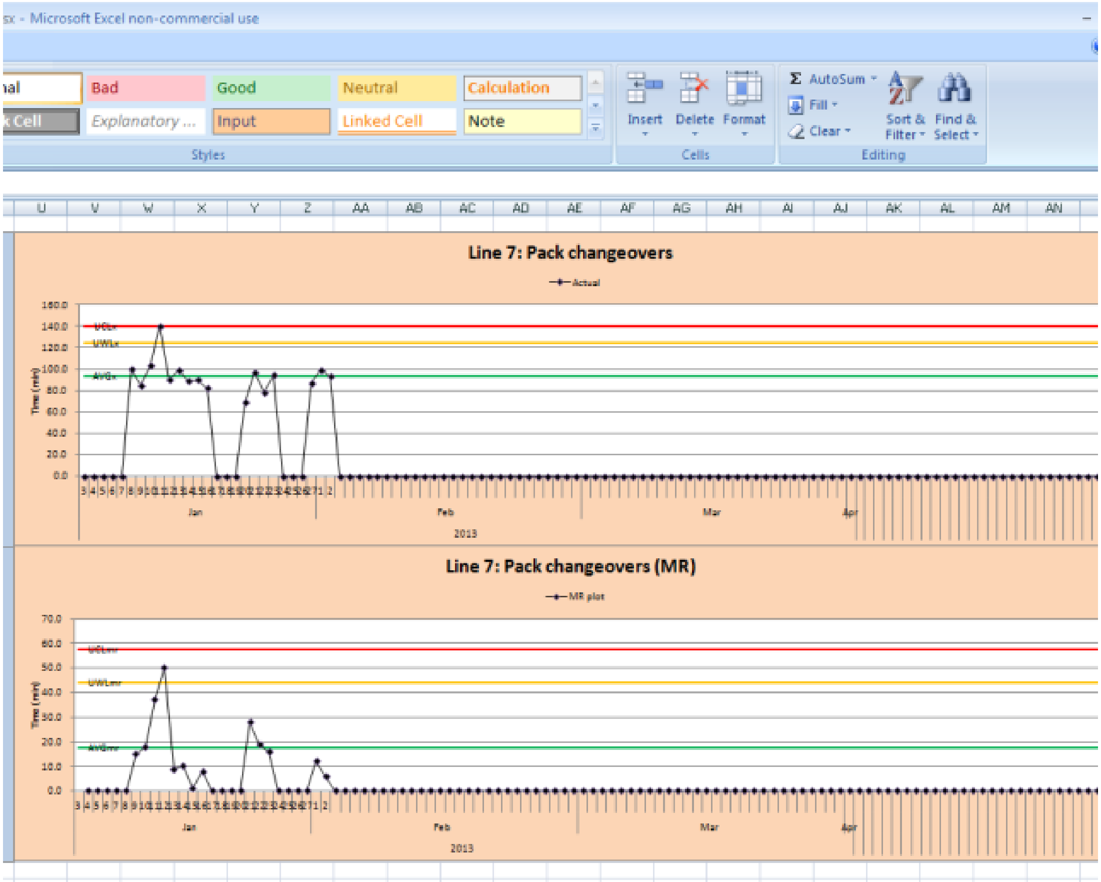


Figure 9: Screen capture of pack changeover graphs

5.3 SMED Analysis suggestions

The SMED analysis on the filler and labeller machines performed in section 4.1 indicated a few actions that could be performed externally as well as shortening the time of some activities that are performed internally.

With the filler the analysis showed that checking the CO parts could be externalised as well as shortening the part fitment and part removal tasks by means of an assistant for e.g. the CO specialist. The total reduction in time from this analysis can reduce the pack CO time possibly from 83min to 64min, which is a total of 19min possible savings.

With the labeller analysis it was found that most of the part fitment can be externalised because the aggregates can be set up externally most of the time. A reduction in pack changes from 77min to 53min could be possible which a reduction of 24min.

It should be noted that these possible saving will probably not be realised to the full extent but may be realised up to 50% margin possibly.

5.4 Update work instructions

The current work instructions are outdated and does not contain information about the brand and packs that is currently being produced on this packaging line. Some procedures on how to do a changeover are not applicable and some needs amendments. It is advised to update these work instructions to ensure future employees are trained correctly and learn the correct procedures. Updated work instructions can also aid in correct performance evaluation of workers and to ensure the current workforce are up to date with the best operating procedures.

5.5 Impact of possible solutions

The financial impact of each solution must be investigated to ensure that the solutions that are implemented contribute to the original aim of the project of reducing the changeover time. It is expected that the change parts management can have an impact due to the current system that causes lots of wasted time due to parts that is not available when it should be.

The data capturing system may not have impact on the changeover time itself, but this will be invaluable to ensure that any improvement efforts are not lost and forgotten. This will ensure that management can trace the performance of the line regarding changeovers.

The SMED analysis improvements might have the biggest impact on changeover time, but the extent of their impact might not be as big as what is anticipated.

5.5.1 Revised cost savings

By adding up the potential time savings the monetary savings can be calculated. The change part management solution will mainly reduce the time if parts are not organised and missing. It’s very difficult to estimate the real impact because each CO renders different problems and searching for parts can range from few minutes to plenty. The estimate impact that this solution will give is reducing the time by 3-4 min.

The SMED analysis showed greater potential for savings. By applying the new To-Be sequence the shortest times of the changeover will be determined by the filler, because the changeover at the filler is the longest. The filler can be reduced by up to 19 min, but this will probably be closer to 10min realistically.

The data capturing sheet will have no impact on reducing changeover times, but it will ensure that management are monitoring the performance of the line. Table 15 shows the potential time savings for brand and pack changes per changeover and Table 16 shows the weekly savings calculated from the same data as from Table 6.

	Solution	Savings per changeover	Realistic
Pack changes	Change part management SMED to-be sequence	3–4 min 19 min	3 min 10 min
		Total	**13 min**
Brand changes	Change part management SMED to-be sequence	3-4min 2min	3 min 2min
		Total	**5 min**

Table 15: Potential time reduction on changeovers

Again the retail value of the products was taken as a basis for calculations at R 6.50 per unit. With a capacity of 700 bottles per minute this equates to R 22,750 saving for brand changes where 5 min are reduced and R 59,150 for pack changes for reducing the time by 13 min. The weekly saving is recalculated in Table 16.

	Average Changeovers per week	Savings per changeover	Savings Total
Brand changes	3	R 22,750.00	R 68,250.00
Pack changes	1	R 59,150.00	R 59,150.00
Total savings per week **Total savings per year**	**208**		**R 127,400.00** **R 6,624,800.00**

Table 16: New estimation of potential savings

From Table 16 it can be seen that a rough estimate can give you up R 130,000 of savings if the full 5 min and 13 min are reduced per changeover. This is close to the initial target of 7min and 15 min for brand and pack changes originally estimated. Thus applying these solutions will potentially increase the weekly savings and solve the problem that was initially stated.

6. Conclusion

This project aim was to use the structured problem solving methodology of DMAIC to find solutions to reduce the changeover time of packaging line 7 at Chamdor brewery. During the Define phase numerous tools were used to establish the problem and understand the boundaries of the project, the problem statement worksheet provided the necessary information to clearly define the process and scope of the project. The high level process map was created as a baseline for the subsequent tools to be used correctly and to provide an overview of the process under study.

In the next phase, Measure, three tools were used to narrow down the area of investigation and measure the process. Historical data analysis was done to provide a measure of the current performance of the packaging line. In this analysis it was found that the current performance for the line is roughly 60 min for pack changes and 30 min for brand changes. It was also established that the target for this project was reducing pack changes by 15 min and brand changes by 7 min. The low level process map was created after the data analysis was done and this documented all the relevant inputs and outputs of the main processes from the high level process map. This served as input data for the C/E matrix which was used to prioritise the most relevant inputs that have an influence on the changeover time.

The third phase called Analyse was started after the C/E matrix was conducted. This consisted of two main tools to investigate the inputs identified in the cause and effect matrix. The first tool was a SMED analysis which mapped out the changeover sequence for the filler and labeller machines. This analysis showed which activities are internal and which are external. The second tool used in the Analyse phase is the FMEA and this showed an in depth analysis of the possible failures of the key inputs and the effect of those failures.

The improvement plan followed the Analyse phase. The improvements were not implemented but were only suggested and implementation is assigned responsibility to the unit manager of the packaging line. There was four opportunities identified, the first is an effective change parts management system, the second a data capturing system, the third is updating work instructions and the fourth is applying the To-Be sequence of the SMED analysis. These four solutions were discussed in detail and the final impact of these solutions was calculated. The potential of these solutions indicated a 5 min reduction in brand changes and 13 min reduction in pack changes. This is very close to the initial 7 min and 15 min and thus this project successfully provided solutions to the stated problem.

7. References

Alexa, V., 2011. Determining the main steps of the SMED method's implementing in the production cycle management of the companies. *Machine Design*, 3(4), pp.285–288.

Anon, 2005. R93m investment in Chamdor brewery. Available at: http://www.engineeringnews.co.za/article/r93m-investment-in-chamdor-brewery-2005-11-18 [Accessed August 6, 2012].

Burcher, P., Dupernex, S. & Relph, G., 1996. The road to lean repetitive batch manufacturing: Modelling planning system performance. *International Journal of Operations & Production Management*, 16(2), pp.210–220.

Gitlow, H.S. et al., 2005. *Quality Management* 3rd ed., New York: McGraw-Hill/Irwin.

Kilpatrick, J., 2003. Lean principles. *Utah Manufacturing Extension Partnership*.

Rebelo, E., 2003. It's Czech mate for top South African brewer. *Engineering News*. Available at: http://www.engineeringnews.co.za/article/itx2019s-czech-mate-for-top-south-african-brewer-2003-08-08 [Accessed May 6, 2012].

SAB internal, 2009. Filler Work instructions.

Salah, S., Rahim, A. & Carretero, J.A., 2010. The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma*, 1(3), pp.249–274.

Shingo, S., 1985. *A Revolution in Manufacturing: The SMED System*, Mass Cambridge: Productivity Press.

Tang, L.C. et al., 2007. Fortification of Six Sigma: expanding the DMAIC toolset. *Quality and Reliability Engineering International*, 23(1), pp.3–18.

Tong, J.P.C., Tsung, F. & Yen, B.P.C., 2004. A DMAIC approach to printed circuit board quality improvement. *The International Journal of Advanced Manufacturing Technology*, 23(7-8), pp.523–531.

Tong, P., 2009. SMED Case study: Steel Tools Manufacturer. Available at: http://www.coe-partners.com/Articles/SMED%20Case%20Study.pdf [Accessed May 3, 2012].

8. Appendices

8.1 Appendix A: List of abbreviations

C/E	Cause and effect matrix
C/U	Controllable/Uncontrollable
CIP	Cleaning In Progress
CO	Change over
DMAIC	Define Measure Analyse Improve Control
Dumpies	340ml Non-Returnable bottles
FMEA	Failure Mode and Effect Analysis
HMI	Human machine interface
NRB	Non-Returnable Bottle
Pints	330ml Returnable bottles
Plc	Public limited company
PSL	Pressure sensitive label
QCT	Quick changeover technology
RB	Returnable Bottle
SAB	South African Breweries Limited
SMED	Single Minute Exchange of Die
WI	Work Instructions

8.2 Appendix B: Full Process map low level

Inputs	C/U	Process	C/U	Outputs
Depal operator	c	Depalletiser	u	Reusable wooden pallets
Forklift	c		u	Scrap pallets
Forklift driver	c		u	Reusable Divider cartons
Divider Cartons	c		u	Scrap Divider cartons
Confirm brand to be run with Filler operator	c		u	Old Brand bottles on line towards filler
Old Brand pallet with bottles	c		u	New Brand bottles on line towards filler
New Brand pallet with bottles	c		u	Recorded counters(Depal)
Program on touch screen	c		u	CO time for Depal + Gap between bottles
Production Plan	u			
Team leader	c			
Counters	u			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Filler Operator	c	Rinser/Filler/ Crowner	u	Bottles of filled beer with Crowns, bad quality
Old Brand bottles on line towards filler	u		u	Bottles of filled beer with Crowns, good quality
New Brand bottles on line towards filler	u		u	CO time for Filler + Gap between bottles
Counters	u		u	Recorded counters(Filler)
CO time for Depal + Gap between bottles	u		c	Old Rinser star wheels
New Rinser star wheels	c		c	Old Filler star wheels
New Filler star wheels	c		c	Old Crowner star wheels
New Crowner star wheels	c		c	Old In feed worm
New In feed worm	c		c	Old Guides
New Guides	c		c	Old Crowns (Unused)
Old Crowns	c		c	Old Change parts trolley
New Crowns	c			
Machine height settings	c			
Settings on the machine (Filler Scada)	c			
Position 2 bolts for indeed worm	c			
Test/Demo bottle	c			
CIP (Cleaning) Program	c			
Sensor on filler(changes for 440)	c			
Start-Up program	c			
Check mate settings	c			
Broom	c			
Water hose	c			
Old Change parts trolley	c			
New Change parts trolley	c			
New Beer/Fab	u			
Old Beer/Fab	u			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Program settings	c	Pasteuriser	u	Pasteurised bottles, bad quality
Operator	c		u	Pasteurised bottles, good quality
Bottles of filled beer with Crowns, bad quality	u		u	CO time for Pasteuriser + Gap between bottles
Bottles of filled beer with Crowns, good quality	u		u	Recorded

				counters(Pasteuriser)
CO time for Filler + Gap between bottles	**u**			
Counters	**u**			
Team leader	**c**			
Electrical Process artisan	**c**			
Mechanical process artisan	**c**			
Change over WI	**c**			
Pasteurised bottles, bad quality	**u**	**Labeller 1**	**u**	Labelled bottles, good quality
Pasteurised bottles, good quality	**u**		**u**	Labelled bottles, bad quality
CO time for Pasteuriser + Gap between bottles	**u**		**u**	CO time for Labeller 1+ Gap between bottles
Counters	**u**		**u**	Recorded counters(Labeller1)
Old Labels	**c**		**u**	Unused Old Labels
New Labels	**c**		**c**	Old Label trays
Labeller 1 Operator	**c**		**c**	Old Tray slides
Wash bath for old brand parts	**c**		**c**	Old label follower
Old Change Parts trolley	**c**		**c**	Old spacers
New Change Parts Trolley	**c**		**c**	Old Wipe down
PSL Aggregate station (Neck)	**c**		**c**	Old Star wheels
PSL Aggregate station (Body)	**c**		**c**	Old guides
PSL Aggregate station (Back)	**c**		**c**	Old in feed worm
Cold Glue Aggregate station (Neck)	**c**		**c**	Old centring bells
Cold Glue Aggregate station (Body)	**c**		**c**	Old Brushes
Cold Glue Aggregate station (Back)	**c**			
Aggregate height settings (Neck, body, back)	**c**			
New Label trays	**c**			
New Tray slides	**c**			
New label follower	**c**			
New spacers	**c**			
New Wipe down brushes	**c**			
New star wheels	**c**			
New guides	**c**			
New in feed worm	**c**			
New centring bells	**c**			
New bottle plates	**c**			
New brushes	**c**			
Cold glue bucket (Neck, body, back)	**c**			
Program on touch screen	**c**			
Camera settings	**c**			
Conveyor bottle size settings	**c**			
Distance Settings between bottle gripper and gripper cylinder(Neck, body, back)	**c**			
Test/Demo bottles	**c**			
Glide liner bottle type settings	**c**			
Distance Setting between aggregate and bottle	**c**			
Team leader	**c**			
Electrical Process artisan	**c**			
Mechanical process artisan	**c**			
Change over WI	**c**			
Pasteurised bottles, bad quality	**u**	**Labeller 2**	**u**	Labelled bottles, good quality
Pasteurised bottles, good quality	**u**		**u**	Labelled bottles, bad quality
CO time for Pasteuriser + Gap between bottles	**u**		**u**	CO time for Labeller2 + Gap between bottles
Counters	**u**		**u**	Recorded counters(Labeller2)
Old Labels	**c**		**u**	Unused Old Labels
New Labels	**c**		**c**	Old Label trays
Labeller 2 Operator	**c**		**c**	Old Tray slides
Wash bath for old brand parts	**c**		**c**	Old label follower

Old Change Parts trolley	**c**		**c**	Old spacers
New Change Parts Trolley	**c**		**c**	Old Wipe down
PSL Aggregate station (Neck)	**c**		**c**	Old Star wheels
PSL Aggregate station (Body)	**c**		**c**	Old guides
PSL Aggregate station (Back)	**c**		**c**	Old in feed worm
Cold Glue Aggregate station (Neck)	**c**		**c**	Old centring bells
Cold Glue Aggregate station (Body)	**c**		**c**	Old Brushes
Cold Glue Aggregate station (Back)	**c**			
Aggregate height settings (Neck, body, back)	**c**			
New Label trays	**c**			
New Tray slides	**c**			
New label follower	**c**			
New spacers	**c**			
New Wipe down	**c**			
New star wheels	**c**			
New guides	**c**			
New in feed worm	**c**			
New centring bells	**c**			
New Bottle plates				
New brushes	**c**			
Cold glue bucket (Neck, body, back)	**c**			
Program on touch screen	**c**			
Camera settings	**c**			
Conveyor bottle size settings	**c**			
Distance Settings between bottle gripper and gripper cylinder(Neck, body, back)	**c**			
Test/Demo bottles	**c**			
Glide liner bottle type settings	**c**			
Distance Setting between aggregate and bottle	**c**			
Team leader	**c**			
Electrical Process artisan	**c**			
Mechanical process artisan	**c**			
Change over WI	**c**			
Labelled bottles, good quality	**u**		**u**	Shrink-wrapped Units, Good Quality
Labelled bottles, bad quality	**u**		**u**	Shrink-wrapped Units, Bad Quality
CO time for Labeller 1 and 2 + Gap between bottles	**u**		**u**	CO time for Shrink-wrap + Gap between bottles
Counters	**u**		**u**	Recorded counters(Shrink-Wrap)
Roll holder (for changing rolls)	**u**		**u**	Old brand film rolls (Unused)
Shrink-Wrap Operator	**c**		**u**	Old Carton bases (12 packs)
New brand film rolls	**c**		**c**	Old metering pins
Old brand film rolls	**c**			
Adjustment handle	**c**	**Shrink-wrap**		
Program settings	**c**			
Change parts trolley	**c**			
New Metering Pins	**c**			
Guide plates	**c**			
Separating plates (add or remove)	**c**			
Revolver Adjustments	**c**			
In feed guide adjustments	**c**			
Cutting Sensor Settings	**c**			
Cutter adjustments	**c**			
Blower angle settings	**c**			
12/6 pack switch setting	**c**			
6/12 pack sensor flaps	**u**			
Old Carton bases (12packs)	**c**			

New Carton bases (12 packs)	c			
Hand forklift	c			
Pallets(with raw material on)	c			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Labelled bottles, good quality	u	**Jones/Carton Erector**	u	Carton units, good quality
Labelled bottles, bad quality	u		u	Carton units, bad quality
CO time for Labeller 1 and 2+ Gap between bottles	u		u	CO time for Jones + Gap between bottles
Counters	u		u	Recorded counters(Jones)
Jones Operator			u	Old Brand cartons(unused)
New Brand cartons	c			
Old Brand cartons	c			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Shrink-wrapped Units, Good Quality	u	**Tray packer**	u	Tray units, good quality
Shrink-wrapped Units, Bad Quality	u		u	Tray units, bad quality
CO time for Shrink-wrap + Gap between bottles	u		u	CO time for Tray packer + Gap between bottles
Counters	u		u	Recorded counters(Tray packer)
Crank handle	c		u	Old Brand Trays (Unused)
Tray packer Operator	c		c	Old metering pins
New Brand trays	c			
Old Brand trays	c			
New metering pins	c			
Pallets (with trays on)	c			
Change parts trolley	c			
Lane plate adjustments(for brand/Pack)	c			
Revolver adjustments(all 4)	c			
Height Sensor Adjustments	c			
Gap detection sensor	c			
Lane guides adjustments	c			
Magazine panel adjustments	c			
Vacuum cups adjustments	c			
Container guide adjustments	c			
Blank feed adjustments	c			
Conveyor width adjustments	c			
Flap folding device adjustments	c			
Adhesive application adjustment	c			
Pack formation width adjustment	c			
Program settings on touch screen	c			
Hand forklift	c			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Handle applicator Operator	c	**12pack Handle applicator**	u	12pack units w/ handles, good quality
New Handle rolls	c		u	12pack units w/ handles, bad quality
Old Handle rolls	c		u	CO time for Handle applicator + Gap between bottles
Shrink-wrapped Units, Good Quality	u		u	Recorded counters(Handle

				applicator)
Shrink-wrapped Units, Bad Quality	u		c	Old handle rolls (unused)
CO time for Shrink-wrap + Gap between bottles	u			
Counters	u			
Program settings on touch screen	c			
Indeed guide conveyors adjustment	c			
Applicator height adjustment	c			
Out feed guide conveyor adjustment	c			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			
Palletiser Operator	c	Palletiser and Stretch wrap	u	Full pallets, good quality
12pack units w/ handles, good quality	u		u	Bad quality rejects
12pack units w/ handles, bad quality	u		u	CO time for Palletiser + Gap between bottles
CO time for Handle applicator + Gap between bottles	u		u	Recorded counters(Palletiser)
Counters	u		u	Pallets (un used)
Tray units, good quality	u		u	Stretch wrap (Un used)
Tray units, bad quality	u		u	Carton dividers (Un used)
CO time for Tray packer + Gap between bottles	u		c	Old gripper pads
Pallets	c			CO time: Gap between bottles (Old brand last good quality until First new brand good quality
Stretch wrap	c			
Carton Dividers	c			
Program settings on touch screen	c			
New Gripper pads	c			
In feed conveyor adjustment	c			
Height detection sensor adjustment	c			
Forklift	c			
Forklift driver	c			
Team leader	c			
Electrical Process artisan	c			
Mechanical process artisan	c			
Change over WI	c			

Table 17: Full process map