ENHANCEMENT QUALITY LEVEL OF PROCESSES IN AN APPAREL MANUFACTURING COMPANY VIA VALUE STREAM MAPPING

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ABSTRACT

‘Ensure Quality’ is an indispensable facet in any manufacturing industry, which is essential to sustain in volatile markets. This has become a widely spoken, an important topic in the arena. ‘Apparel ‘the highest income gainer of Sri Lankan Economy is in a gloomy situation, struggling with immense challenges prevailing. Favorable acknowledgement about the quality of Sri Lankan produced garments stow a hope in our hearts, where a study about the matter is undoubtedly escort benefits for the industry. This study is undertaken with a view to enhance process quality of Value Streams of main customers in a leading apparel manufacturing company in Sri Lanka. In order to identify quality improvement opportunities, VSM’s were developed for selected customers and identified most crucial processes needs to study on. It was able to distinguish cutting/molding, production and AQL processes are pivotal processes which contribute in generating of VSM’s . It studied process wise types of defects occurred as well as causes for such occurrences. It emphasized production process consists higher defect percentage than the other processes. The study elaborated to check whether the quality level of production processes of all customers lies within the statistically in control levels. The study revealed that all processes are within the control limits.. With the aid of statistics and Lean Manufacturing tools production processes deeply studied. Actions were taken for identified improvement opportunities and re-checked the quality levels. Results stipulated that the quality level of production processes is being improved. Similarly, its consequences the production processes are statistically capable. Study further elaborated to check the capability of the plant quality process and sample size daily examined. The study reveals that the plant quality process and daily examining sample size are inadequate. It is recommended to improve the plant quality process and to increase daily auditing sample size.

Keywords: AQL process, cutting /molding process, process map, production process, Value Stream Maps (VSM).

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TABLE OF CONTENT

TABLE OF CONTENT CONTINUED

TABLE OF CONTENT CONTINUED

LIST OF FIGURERS

LIST OF FIGURERS CONTINUED

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Explanation
VSM	Value Stream Map
VS	Victoria Secret
AQL	Acceptable Quality Level
LCL	Lower control Limit
CL	Control Limit
UPL	Upper Control Limit
CK	Calvin Klein
PDCA	Plan, Do, Check, Adjust
STW	Standard Work

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

World of business changes every day, every hour. Numerous business entities enter into the market without a pause, therefore an inconceivable competition is created. In order to survive in a highly competitive market it is essential to increase the organizational productivity as well as the quality of the product (Rohani & Zahraee, 2015). An occurrence of minor defect in such a competition can cause a turmoil for the entire manufacturing company. Deviation in Required Quality Level from the Accepted Quality Level creates not only the customer dissatisfaction but also shipment delays as well as production losses. Therefore, it is visionary to attain customer's expected quality level at the first instant. To accomplish this task, organizations follow Lean Manufacturing System uses Value Stream Mapping which is considered as one of the key tools in Lean Theory.

Occurrence of waste in manufacturing processes causes considerable inefficiencies in the business. In 2001 a study was undertaken about how Value Stream Maps support in redeeming waste in business models. According to the results obtained, it reveals carefully designed model enables decision makers in identifying irrelevant activities and processes which has been built within the Main Process (Giaglis, 2001). Value Stream Mapping has been accepted for its effectiveness in identifying and eliminating waste in business process and increase quality level. This is also renowned for its proficiency in successive decision making.

A company needs to identify its own potentials to survive in a highly fluctuating market. All the processes within the organization should be optimized and operational inefficiencies should be improved to accomplish this task. Value Stream Maps come in handy in this regard. One of the most important fact of a successful management is high quality decision making within a smallest possible time. Therefore, it is necessary to focus on aligning the available processes according to the business requirements which supports the organizational managements' in achieving organizational goals.

Business entity sustainment largely depends on future market opportunities and its plans for the future. Therefore, it required formulation of business strategies to achieve organizational goals. Value Stream Maps derives the strategies for the organization. It provides a better insight in identifying the current stage of the processes and how the future stages should be designed. Similarly, it depicts how to agile existing Value Streams according to the future business requirement.

The apparel manufacturing is a paramount industry in Sri Lanka which brings in highest foreign exchange compared to other industries. The industry faces multiple challenges for its survival, such as tremendous competition, taxation policies, inability to attract workforce and so on. Quality level of Sri Lankan products has been acceptable in the international trade than products coming from our regional competitors such as India and China. We were fortunate to win production orders from world renowned customers such as Victoria Secrets, Nike, Gap, Calvin Klein by defeating our competitors in biddings due to higher quality levels. Thus, maintenance of quality in the apparel industry is an indispensable facet to accomplish with.

To ascertain the quality of a garment, it is essential to establish the quality level of entire Value Stream where the garment flows on. Therefore, amplify and ensure a quality level of Value Streams is a committal scripture to adhere on.

1.2 Objectives

The objectives of the research are to:

- Develop Value Stream Maps for selected styles of major customers
- Identify most crucial processes of the Value Stream needs to study
- Observe current quality levels of the chosen processes and determine the most crucial process need to study further
- Analyse chosen process using Statistical Quality Control and Lean Manufacturing tools, and identify quality deviations from the standard
- Disclose root causes for the occurrence of defects and quality improvement opportunities of the processes
- Determine sample size needs to inspect daily according to plant AQL requirement
- Figure-out capability of the plant Quality Process

1.3 Significance of the Study

The findings of the study are undoubtedly beneficial for both companies' as well as employees' perspectives. Enhance process quality level, system modification, implement required new processes, is able to fortify customer satisfaction as well as increase profitability. This study is competent to improve Strategic Decision Making of the Management . Smoothly driven processes facilitate complacency of jobs, simplify effort, improve productivity, and trigger shifts of processes in a quick stance, so do enhance the take home salary of employees. The findings of this study will be beneficial for future trainers, researchers and others in the industry.

1.4 Limitations of the Study

This study was restrained to a single manufacturing plant (named as ‘A’) out of many plants dispersed throughout the country. Due to the magnitude of the company and diversity of the product ranges the study has been limited to a plant which produces only bras. From among the several foreign and local customers only seven customers were chosen whose production volume is higher than the others. As Value Streams of selected customers are spread throughout the world, part of the Value Stream only applicable to plant ‘A’ was selected due to availability of time and other resources. Detailed version of Value Stream Maps was not used for the study as it considered only a Quality improvement.

CHAPTER 2
LITREATURE REVIEW

2.1 Quality Control

No production process can produce exactly alike products. All the goods produced contains a certain level of variations due to unavoidable variability (Leavenworth & Grant, 2000). Such variability depends on many factors such as Man, Machine and Method. It is utmost important to limit the variability between specified upper and lower limits of the quality characteristic of consideration. The variance of the production process can occur in a pattern or randomly due to the underlying causes. To identify deviations of the process from the standard, Control Chart has become a widely used Statistical Quality Control tool. Product quality is positively correlated with the manufacturing plant's capability (He & Yu, 2018). It also depends on the input material's quality. Firms that use high quality inputs alongside with higher capability produces better finish goods.

The success of a product depends on the satisfaction of the customers (Mrugalska & Tytyk, 2015). In order to accomplish this task minimum variation of the parameters of the product life cycle should be ensured. Product quality, reliability and safety interconnected with each other which affected in satisfaction of the customer. The reliability and safety's aim is to study, characterized, measured, analyses repairs, and identify improvement opportunities of the product.

There are three main steps in a Statistical Control Process (Shewhart, 1986) ,specification of the company's need, manufacture according to standards and inspect the products to verify achievement of required standards. Exceeding beyond the specified quality range, a product considered to be a defect. To rectify and identify defects costs money for the company. By a process improvement it can reduce the number of defects occurred which safeguards a huge sum for the company.

Change in the quality of a particular product caused due to deviation from the Standard. Defects occur due to two key reasons, namely Assignable Causes and Unassignable Causes (Shewhart, 1926) .

It is utmost important to setting up a practical set of procedures to convey the needs of customer requirements, throughout the Value Stream (Matzler & Hinterhuber, 1998). The message communicates relevant parties through value stream which guides them in exceptional product development based on customer's quality requirement.

2.2 Value Stream Mapping/Process Mapping

Value Stream Map act as a communication tool, a business planning tool as well as a tool to manage change in a business process (Rother & Shook, 2003). Value Stream of a particular product family consists all the processes contributed in the creation of that particular product. Tracing Value Stream of a product family eventually guides to look across the entire organizational boundaries as processes from designing stage to handover finished goods to the customer belongs to a Value Stream of a certain product. It is defined by the phrase 'from the molecule to customer's arm'. Improving Value Stream means not optimizing simple parts, but to improve the entire process. Value Stream Map is a pencil and a paper tool which shows the material and information flow alongside with the product. It provides a clear idea about the waste generated within the process in mean time supports reducing them in spite of creating a more efficient Value Stream.

During past years, many organizations tend to practice Lean Manufacturing System (Seth & Gupta, 2005). Value Stream Map has been distinguished for its effectiveness in identifying and removing waste in a considered process, while facilitating improvement opportunities in similar product routines as well. This methodology is beneficial in identifying accurate per person work load, inventory level and work in progress levels which paves the way in productivity enhancement.

Value Stream Mapping is one of the best ways to identify the criticalities in a production process (Braglia, Carmignani & Zammori, 2006). It is beneficial if analyze iteratively so it is easier to identify the optimum critical path of the Production Process which reduces the work in progress into a desired level. This tool can easily apply in simple processes, but cause difficulties when applying in complex production systems.

It is a widely used lean tool which facilitates in identification of the Current State of the considered process and hurdles need to overcome in achieving the Future State of the process (Chen, Li & Shady, 2010). This also illuminates Kaizen (small improvements) opportunities.

Physical factory layout arrangement which consumes a higher cost can be reduced by design using simulations and Value Stream Mappings. (Lian & Landeghem, 2002). Use of simulation as a part of Value Steam Mapping informs management about the effects of the changes that are about to carry out. Thereby, the process improvement will result in a reduction of rework, Throughput Time, Lead Time and Work In Progress which creates a Lean culture throughout the manufacturing company.

Value Stream Mapping embedded with the simulation results in the creation of motion free production lines (McDonald, Aken & Rentes, 2002). Simulations can be used to identify the solutions to the questions that are unanswerable by Value Stream Mapping only.

Though Lean is born in the automotive industry it has been applied to many other manufacturing floors during the past few decades. Value Stream Mapping is one of the key Lean Manufacturing tools used to identify the opportunities for implementing various Lean techniques. This will lead in the reduction of production Lead Time as well as lower Work In Progress inventory. VSM is a virtual tool which supports in identification of hidden waste as well as the sources for such occurrences as it clearly shows value adding activities and non-value adding activities. Two maps are developed , from the Current State map it depicts actions which are actually used in production floor while from the Future State map the expectation after reducing wastes through improvement shows (Rahani & Al-Asaf, 2012).

Value Stream Mapping is a key tool used in Lean Manufacturing for visualization and rationalization the processes entailed in the industry (Rohac & Januska, 2014). Clarity is a key advantage of VSM. It visualized door to door all transportation and transforming processes, from raw material input to finished and semi-finished goods delivered to the customers. Outcome of a Value Stream Map is a diagram which represents the value flow of the manufacturing company. In the VSM flow diagram it calculates the indicators used for solving current problems in the process as well as predictions for future improvements which might occur. One of the key features of Value Stream Mapping is to rise with the level of the Management. VSM paves in identification from a small level of Kaizens or improvement opportunities to mega level strategic and capital investment opportunities in the journey to accomplish missions of the organization. It is a supportive tool to identify Bottle Necks and potentials of the Production Process.

In order to survive in a highly competitive world, it has to increase the organizational productivity as well as the quality level of the product (Rohani & Zahraee, 2015). Using Lean tools, it is able to identify Throughput Time, Value Adding Time, Bottlenecks, Takt Times, which provides a clear vision in decision making.

Process modeling is a tool which copes between production planning and control (Becker, Rosemann & Uthmann, 2000). This tool directly impacts economic efficiencies of the underlying processes. Business process development is a crucial task to accomplish with, since even a slightest mistake might cause expensive misjudgments in organizational levels. One of the key aspects which needs to consider in a Business Process Development is to ensure the Product Quality as well as the Process Quality itself. Another task needs to consider in the Business Process Development is fitness for use of the Process.

When developing a new Business Model there are many areas need to be considered (Karagiannis, Junginger & Strobl, 1996)Being a supporting framework which enables the future business requirements, integrate the existing and new technologies into the industries, providing a continuous performance methodology to monitor and improvement purposes of the running business are key points need to adhere to.

Process Modeling is the core of organizational design (Giaglis, 2001). The carefully designed model enables decision makers in identifying the irrelevant activities and processes built within the main process. Change in organizational processes is not an easier task as organizational dimension are interrelated and interacting. By simulating different layouts, alternative techniques and considering suggestions for all levels of employees, comparing the results in a structured way, supports in developing an excellent Organizational Design as well as successive Business Process Engineering.

CHAPTER 3

METHODOLOGY

3.1 Data Sources

The company considered for the study is a prominent advocate of the Apparel Manufacturing Industry in Sri Lanka, which subsist of three main divisions Intimates Wear, Apparel Wear and Fabrics. Portfolio of product categories bra, brief, performance wear, shape wear, sleepwear and lifestyle wear is manufactured in 13 intimates manufacturing plants dispersed throughout the globe. Some plants produce a mix of product types. Value Streams of those plants are complicated and hard to study with the available time period. In order to obtain results with the resources available, the data was gathered from an unalloyed bra manufacturing plant which is denoted by plant ‘A’.

About 95% of the plant capacity has been covered by products of 7 key customers. Victoria’s Secret is the main customer alongside with worlds renowned brands such as Soma, Gap, Calvin Klein, Amazon, Amante and Athleta.

3.2 Process Selection

Mapping detailed version of Value Stream of the products is a difficult task to accomplish with the time injunctions. Therefore, the Value Stream Maps within plant ‘A’ premises were chosen for study. There is more than one style of considered customers, fulfilling the production capacity. With the time and the resources available, the Value Stream Maps were created only for styles consist with the highest quantity of above-mentioned customers. Thereby it identified most crucial processes need to study are Cutting/Molding, Production and AQL processes.

3.3 Data Collection and Analysis

Initially, daily defects percentage occurred in selected processes of the chosen seven customers were gathered. For example, Victoria Secrets style 1, percentage defects as well as types of defects occurred in Cutting/Molding process, Production process and AQL processes were collected. Thereby discovered the highest type of defect occurred in each process. By screening collected data thoroughly it identified the process whose quality level deviates the most.

In this study it spotted that the production process of all customers consists highest defect percentage compared to Cutting/Molding and AQL processes. Study further elaborated to verify whether the production lines which produces the chosen styles are being statistically under control. There, it identified the lines that shows highest variation from the standard.

Aftermath, all processes contributed in constructing the Value Stream of that particular line were tested using acceptance sampling test to verify Statistical capability. It further tested using Statistical Quality Control and Lean Manufacturing Tools and identified root causes for occurrence of deviations. After rectification of defects, process re-evaluated using Acceptance Sampling test, where it verified that process is Statistically capable. Finally, plant Quality Process Capability and AQL sample size need to examine was tested.

3.4 Quality

‘Quality’ of a product or service is considered as meeting the customer requirement sufficiently. In order to analyze a quality of a particular product, 8 dimensions of quality characteristics are used.

First dimension of quality is Performance. Operating characteristics of a good is considered as the Performance of that particular good. For example, in automobile industry traits such as speed, comfort, acceleration are considered as the Performance of that particular vehicle. The second scale of quality is Features of the product. Which means the additional service provided to the customers such as automatic color tuner in television set. Reliability is another dimension of product quality which depicts how often the product fails. Durability is the fourth measurement type of quality. The life span of a product is considered as the Durability of the product. Serviceability of the product is another dimension of the quality which describes the easiest to service the product. Seventh dimension of quality is Aesthetics of the product is a personal judgment about the product such as how the product looks, feels, tastes etc. Final dimension of quality is Perceived Quality or reputation of the particular company. It is intuitive that a customer judge the quality by considering the pervious quality of the products manufactured by that particular company.

3.5 Statistical Quality Control

Statistical Quality Control is the statistical approach to monitor and control quality level of a product or service. It is also known as a strategy for reducing variability of the product and service, identify causes and sources of variability, modify the system . Therefore, it’s not solemnly a process improvement, but also behavioral, cultural and attitude shift of human resource involved with, is considered in this regard.

There's always an inherent variability of manufacturing output, which need to ensure that it doesn't trespass boundaries of customer requirements. Statistical Quality Control comes in handy in this regard. Control Charts provides the ability to visualize the actual scenario arise in the production process, thus supportive accurate decision making.

3.6 Statistical Quality Control Tools

There are seven basic tools used in statistical quality control process to detect and control the quality in an informative way. These tools are highly recognized for its ability to narrate data into a fruitful informative way. In same time due to simplicity, powerfulness and applicability of problem solving they can be used in any industry irrespective of the manufacturing product.

3.6.1 Fish bone diagram or Ishikawa diagram

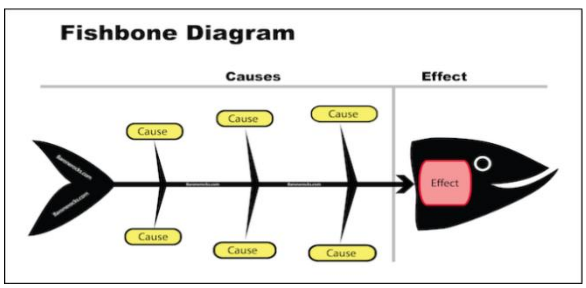

Figure 3:1 Fish Bone diagram

Source: https://www.baronerocks.com/index.php/mnemonics/468-fishbone-diagram

Fish Bone diagram or cause effect diagram is a widely used tool in industries in order to identify causes of a particular problem. In this method, elements of the problem (defect) are classified under divisions of Man, Method, Material, Environment or Information. Thereby it eases identifying root causes of the defect.

3.6.2 Check Sheet.

It is a document used to collect both quantitative and qualitative data for the purpose of analyzing. Due to the simplicity of the method, it is widely used in many industries. Check Sheet is renowned for its usage when data can be gathered by the same person at the same location, data is collected from a pattern of events, as well as when data collected from a production process.

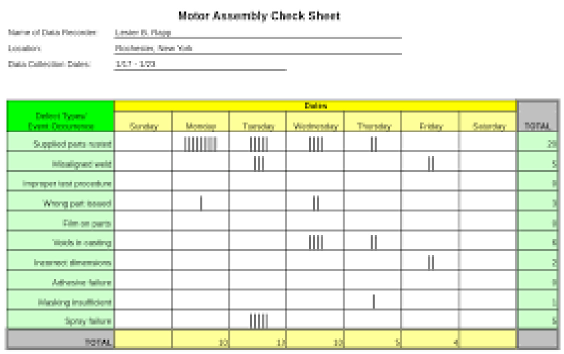

Figure 3.2 Check Sheet

Source: https://www.latestquality.com/types-of-check-sheet/

3.6.3 Control Chart

Statistical Process Control method or Probability Control Chart method is another type of statistical quality control tool. This is suitable to monitor the quality of an ongoing process. If the quality level of the Production Process is in between Upper Control Limits (UCL) and Lower Control limits (LCL) of the Control Chart, then the Production Process is considered to be statistically in control.

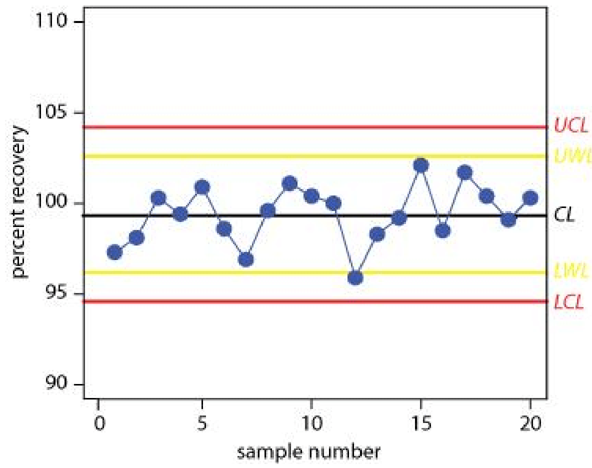

Figure 3.3 Control Chart

Source : https://www.researchgate.net/figure/Example-of-control-chart-Source-Harvey-David-2013-Available-from_fig1_313636387

There are two types of control charts, charts that display attribute data and charts display variable data.

Attribute data display control charts are created from the samples which display count of items of passed/failed, accepted/defects, etc. Variable data display control chart are created from the samples that display measurements of a continuous variable such as temperature, time and so on.

Table 3.1 Types of Process Charts

Chart	**Monitors**	**Application**
X bar and R	Average and Range of the process	Single characteristic and high volume data where sample size is more than 2 and lesser in the count
X bar and S	Average and Standard Deviation of the process	Single characteristic and high volume data where sample size is more than 2
np charts	No of defects	Suitable for discrete attribute data (Pass/Fail), when the sample size is constant

P charts	Proportion of defects	Pass/Fail constant sample size np>3, better to use in short production runs
C chart	Number of defects	Constant sample size, multiple types of defects, opportunity of the occurrences are equal
U chart	Number of defects per unit	Variable sample size, multiple number of defects, opportunity of occurrences is not equal

3.6.4 Histogram

The histogram is another quality control tool which represents the way data is distributed. It clearly illustrates whether the data achieve customer requirement, availability of outliers, skewness and occurrence of changes in the process. Height of bins are marked proportionate to the frequency. Therefore, it clearly visualizes the pattern of data.

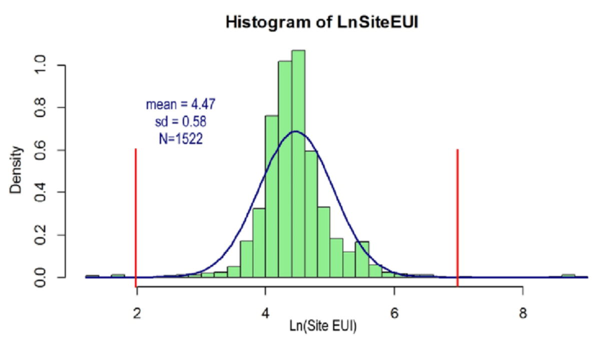

Figure 3.4 Histogram

Source: https://www.researchgate.net/figure/Histogram-of-the-natural-log-of-the-site-EUI-in-kBtu-ft-2-of-all-Chicago-properties_fig1_320203021

3.6.5 Pareto Chart

Pareto chart is another type of quality control tool consists of both lines and bars. Bars represented root causes and aligned in descending order while lines represented the cumulative sum of the figurers. The purpose of a Pareto chart is to visualize the factors which contribute most for a matter of consideration.

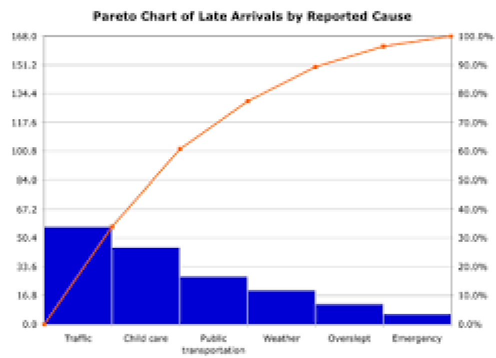

Figure 3.5 Pareto Chart

Source:https://whatis.techtarget.com/definition/Pareto-chart-Pareto-distribution-diagram

3.6.6 Scatter plot

A scatter plot is another type of quality control tool which stipulate the condition of the relationship between variables. If data are scattered as in graph one, factors are considered as positively correlated. If data are scattered as in graph two factors are considered as negatively correlated. If data are scattered as in graph no 3 then it is considered as the factors of consideration are uncorrelated.

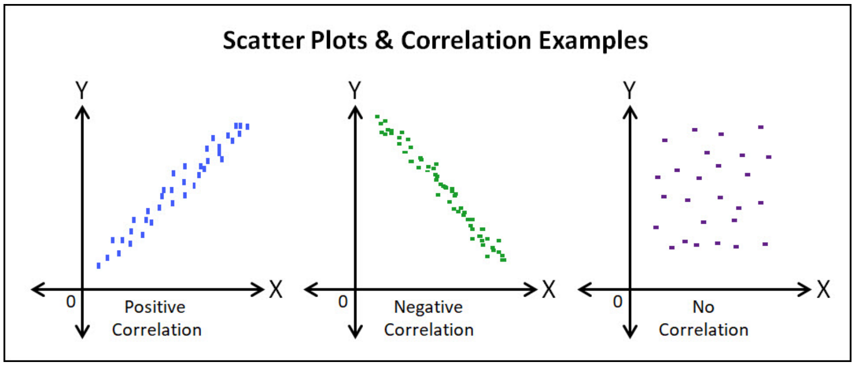

Figure 3.6 Scatter Plot

Source: http://www.cqeacademy.com/cqe-body-of-knowledge/continuous-improvement/quality-control-tools/the-scatter-plot-linear-regression/

3.6.7 Run Chart

Run Chart is a powerful tool which provides the ability to identify trends, performance as well as shifts in the processes of consideration. It provides benefits such as visualized even small shift of the process, pinpoint the spots needs corrective actions, before after states of the process of consideration.

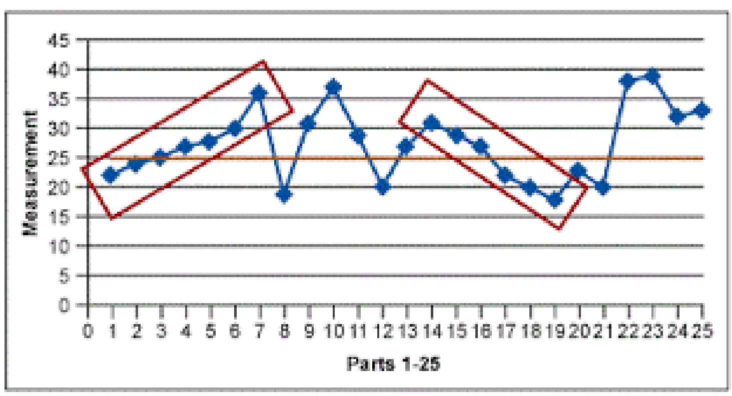

Figure 3.7 Run Chart

Source: https://www.isixsigma.com/tools-templates/control-charts/run-charts-a-simple-and-powerful-tool-for-process-improvement/

3.7 Lean Manufacturing

Lean manufacturing or Toyota Manufacturing System is a revolutionary system in manufacturing and services industries across the globe for many years. In order to sustain in highly competitive markets, Lean Manufacturing's guidance for the industries has been remarkably admired and proven results. There are two key purposes of this world class manufacturing system, to ensure customer satisfaction and enhancement of organizational profitability.

Lean manufacturing is the systematic approach in identifying and eliminating waste or non-value-added activities through continuous improvement by producing goods on time with best quality and lowest cost. Toyota Manufacturing System is a combination of Lean Tools and Lean Rules.

3.8 Lean tools

There are eight Lean Tools those are highly recognized in transforming a manufacturing industry into an operational excellent practitioner.

Quick Change Over: When a product change from one product to another, it requires a considerable time amount to set up machinery and to teach the job need to perform by the Team Members. If a higher time consumed by the changeover it reduces plant capacity, increase number of labor requirement as well as the Lead Time. Therefore, manufacturing plant's practices Lean pay special focus in this area

Kanban: Is a Japanese term used for signaling. Lean Manufacturing System following plants use this method to signal supportive departments to request support to ensure continuation of the production. For example, a Kanban is used to request refill the RM bins.

Yamazumi: Is a visual chart that shows individual activities in stacks by categorizing them into Value Adding, Non-Value Adding and Waste. Yamazumi provides insight about Waste needs to remove on, Non-Vale Adding activities need to reduce and Bottlenecks need attention. Solving these matters improves process efficiencies.

PDCA: Plan, Do, Check and Adjust cycle or Shewhart Cycle used in process adjustment and continuous improvement of that particular process. All the activities are advices to plan thoroughly, implement, check and adjust , thereby achieve better results. This is a never-ending cycle.

Error Proofing: Particularly a device or a method used to identify, correct and highlight an occurrence of an error. For example, implementing red light for heavy machines to visualize when they are in use.

Standardized Work: Detailed definition of the best method to perform a particular work is known as Standardized Work. This is beneficial in obtaining required output with a higher quality with a lesser effort.

Total Productive Maintenance: Focusing all the equipment's performance in the best conditions which supports in a smooth production flow. Maintenance and improvement equipment and tools so they can perform in their best conditions and avoid breakdowns is the key focus of this Lean Tool.

5 S: Is the base of Lean Manufacturing. Creating a well-organized, efficient work place is the focus of this tool. Sort, Set, Shine, Sustain and Standardization together are called 5S.

3.9 Lean Rules

There are four rules in Lean Manufacturing Systems which lays foundation for a structured organization.

First rule: Every work has to be highly specified in to content, sequence, timing, and outcome. This eases the work of employees as well as guided in identification of improvement opportunities

Second rule: Every customer and a supplier should be directly connected, There should be an unambiguous way to send requests and receive responses which creates less customer frustration.

Third rule: Every product or service must flow along cleared specified pathways.

Fourth rule: Any improvement has to be made in a scientific method, under the guidance of a teacher, at the lowest possible level in the organization.

3.10 Waste

An activity that doesn't add value is considered as a waste. According to Lean Manufacturing System there are seven wastes which should be eliminated from the processes.

1. Transportation of material from one place to another occurs due to inappropriate layout design as well as due to the length of the equipment used. This might cause Non-Value Adding alongside with a reduction in the quality of the product.
2. Excess Inventory is considered as another type of waste which hides real problems in the process, delays Lead Time, consume space as well as hide improvement opportunities in the underlying process.
3. Unnecessary Motion is also considered as a waste. Unnecessary bending, stretching, lifting which creates ergonomic related issues belong to these categories.
4. Waiting for work is the forth waste. This occurs due to poorly designed material flow, lengthy production runs.

5. Over Production is also a waste according to Lean Manufacturing System. This lead company to bare unnecessary cost of storage and rectifying defects.
6. Over Processing is the sixth waste. In Toyota Manufacturing this waste is eliminated by investing in smaller flexible equipment s', low cost autorotation, and so on.
7. Defects is the seventh type of waste directly impact to customer satisfaction, the good will of the company and the Bottom Line. Defect repairing requires a huge effort, time as well as the resources of the company.

3.11 Value Stream Maps

It is a Lean Management tool which provides an insight to management in identifying Current State, Future State and gap, of the Value Adding Processes. Value Stream Maps are usually created from supplier to customer covering entire Value Stream. It supports users to identify, and develop Interventional ideas (Lee, Grooms, Mamidala & Nagy, 2014).

3.12 Process Maps

Process maps are a visualizing way of Value Adding functions (Processes) of a Business Organization. It provides an insight about the way that Value Adding function and information flow is connected. Furthermore, it is useful in identifying wastes, inefficiencies inbuilt in the processes as well as the improvement opportunities.

Lean Manufacturing concept practicing companies is using structured, scientific problem-solving methodologies to solve problems. Structured problem solving reduces time in debate, identify weaknesses in the process and systematic causes quickly.

3.13 5Y problem solving methodology

5Y problem solving is the simplest and most popular problem-solving methodology used in Lean Manufacturing System in order to identify root causes of a problem occurred. The way of practicing 5y problem solving is to figure out the root cause of the problem by asking 'why'. Basically 5 iterations of Y's enough to obtain the root cause. Answer for a particular why sets the basis for the next question.

Eg: Problem-Stain marks occurrence

Why stain marks occurred?-due to oil leakage of the machine

Why Oil leakage of machines occurs?-Since machines stationed in lines are not serviced

Why there are not serviced machines stationed? **-**Since there is no mechanism to provide like new conditioned machines to the line

Therefore, it is needed to establish a process to service machines. So, it can reduce occurrence of these type of defects.

3.14 Acceptance Sampling Test

It is a Statistical sampling methodology used to decide acceptance or rejection of a sample lot, based on the number of defects in it. For the analysis, from lot of M, a sample size of N is selected (N<M). Based on the customers' quality requirement acceptance number B is insisted. At the end of inspection if the number of defects found is less than or equal to B the lot is accepted else rejected.

In this study 100 consecutive garments at each process Cutting/Molding, Production and AQL processes were examined and determined whether the lot is accepted or rejected. (100 garments/panels which is around 20% of daily output, were used assuming 80% of defects can be identified if 20 % sample size was used. (Daily output= 450 garments approximately, 20% sample size=90 garments, round off value= 100 garments/panels))

Results obtained from the study revealed that all processes of considered for all 7 customers except Production Process are accepted. In Production Process root causes which are the origins of the defects is analyzed using Fishbone diagram and 5Y mechanism. After rectifying the causes for the occurrence of the defects, again production processes were re checked for 100 consecutive garments and examine the occurrence of defects.

The study is elaborated to check the capability of the plant quality process.

3.15 Process Capability Analysis

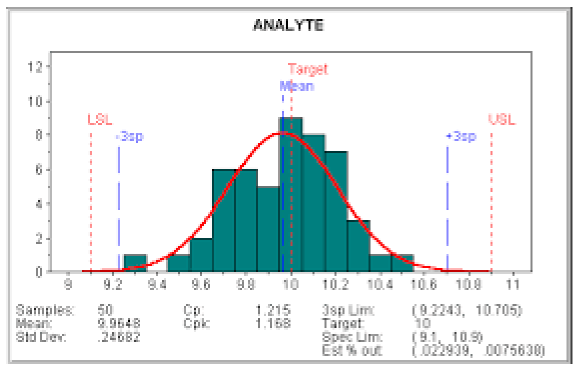

Figure 3.8 Process Capability Chart

Source:https://www.nwasoft.com/resources/information-center/article/process-capability-analysis-laboratory-quality-control

It is a calculation methodology which ensures the process of consideration is systematically within the specification limits. Those specification limits are numerical values expected the system to be operated within. For Capability Analysis data required should be statistically stable. Main indices used are Pp and Ppk. If Ppk>1 then it concludes that the system functions within the requirement. If Pp>Ppk it concludes that the sample mean is close to one specification limit and if Pp=Ppk then mean is closer to middle value of the specification limits. This chart summarizes the capability of the process, extend the improvements needed, so do the improvement achieved.

3.16 Dot Plot

Figure 3.9 Dot Plot

Source: https://study.com/academy/lesson/dot-plot-in-statistics-definition-method-examples.html

One of the simple statistical graphs which visualizes count of data points belongs the categories of consideration.

3.14 Softwares'

For the analysis, Minitab 2017 version, Microsoft Word packages were used.

CHAPTER 4

DATA ANALYSIS

Value Stream Map is a Lean Manufacturing Tool which guides in identifying 7 wastes inbuilt in processes as well as improving process quality by eliminating them. In order to obtain more accurate data, component (particles create a garment) wise VSM's can be developed .

4.1 Victoria's Secret Style (i)

The Value Stream flow of the wing and center front components of the garment can be illustrated as follows.

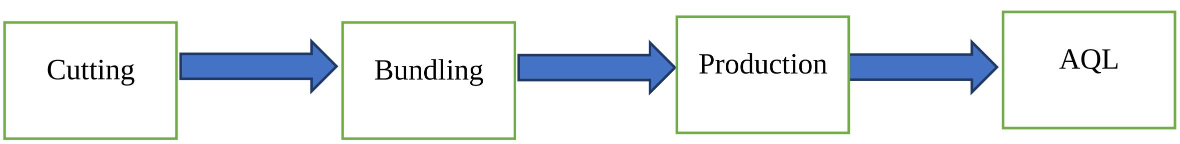

Figure 4.1 VSM of VS C/F and Wing components

Value Steam Map of the cup components of the garment can represent as follows,

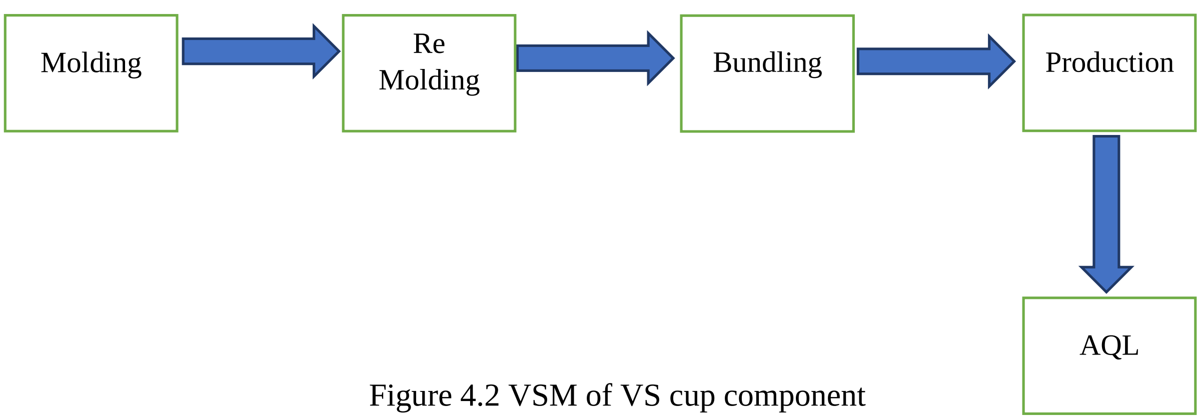

Figure 4.2 VSM of VS cup component

According to the VSM's it is clearly visible that Cutting/Molding, Production and AQL processes are the main processes involve in the creation of VSM of VS style 1. Therefore defect percentage reported in Cutting/Molding, Production and AQL processes of VS style I was gathered.

Table 4.1 Defects percentage of VS style 1

Process	**Defects**
Cutting and molding	5%
Production	10%
AQL	3%

Above table consists of defects percentages occurred in considering the processes of VS customer style 1. Defects and causes occurred in each segment of Value Stream can be explained as follows.

In Cutting and Molding process, 1% of defects occurred due to panels not matching with the pattern, 0.8% defects occurred for the cause of molding not fitting with the hat, 1.2% defects occurred as a result of molding burn and 2% of defects occurred due to incorrect grain lines. Thus, it reveals highest defect percentage occurred in Cutting and Molding process is due to molding burn.

In Production Process 0.3% defects occurred due to size mixed up, 6% defects occurred for wing height uneven, 1.7% defects occurred cause of stain marks, 1.7% defects occurred due to channeling code uneven, 0.3% defects occurred cause of cut damages, 0.3% of defects occurred for uncut raw edges in bar tack ,0.3% of defects occurred due to snagging and 0.3% defects occurred for the cause of sheering in cup.

According to the analysis in AQL process, it reveals that 0.7% of defects occurred due to stain marks, 0.2% defects occurred for cup sheering and 2% of defects occurred due to wing height uneven. The highest percentage of defects occurred due to height uneven.

It is evident that Production Process consists with highest defect percentage compared to other processes. Therefore, Production Process is thoroughly analyzed to identify causes for the occurrence of defects.

4.2 Soma style (i)

Following is the Value Stream chart of the Center Front component of the garment.

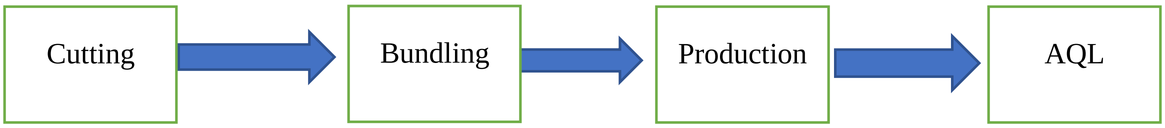

Figure 4.3 VSM of Soma center front component

For the cup components of the garment, Value Stream chart can be represented as follows.

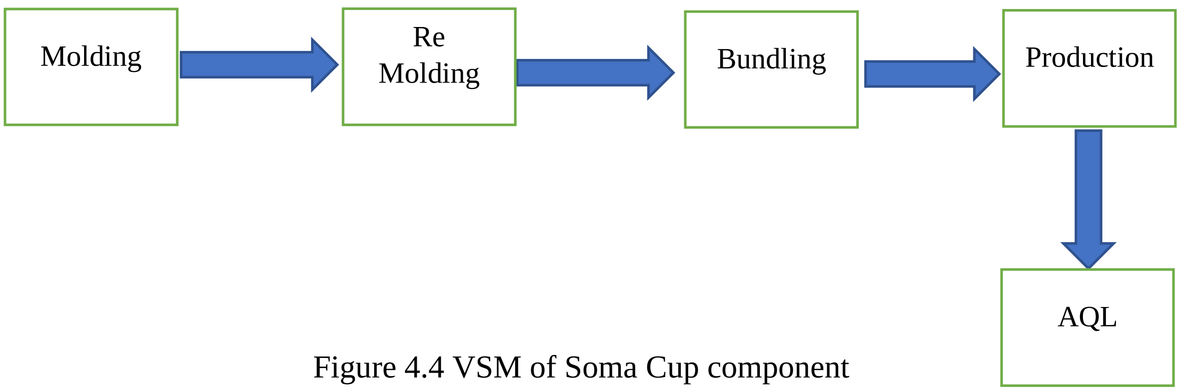

Figure 4.4 VSM of Soma Cup component

The Value Stream Map for Soma style (1) wing component is as follows.

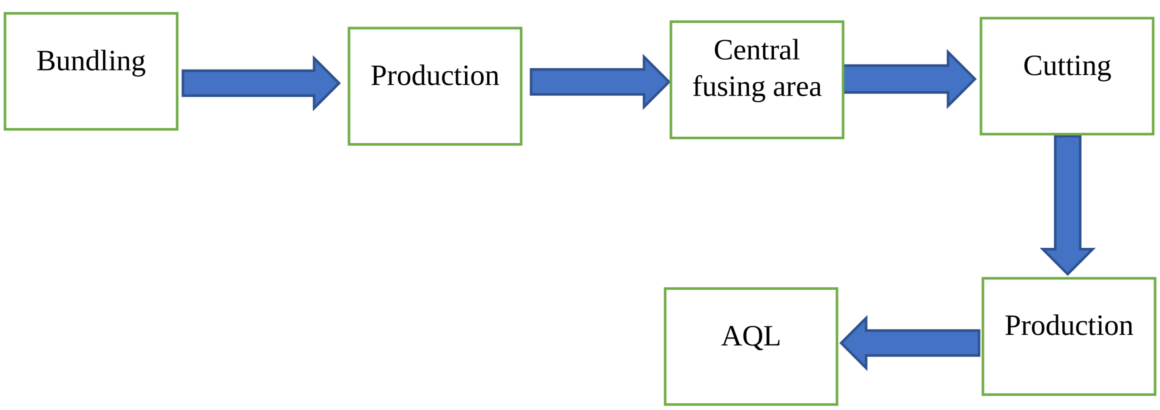

Figure 4.5 VSM of Soma Wing component

Soma style 1's considered process wise defects occurred can be represented as follows,

Table 4.2 Defects percentage of Soma style 1

Process	Defects
Cutting and molding	8%
Production	10%
AQL	5%

According to the analysis carried out defects occurred in processes of Soma style 1, can be explained as follows.

In Cutting and Molding Process defects occurred due to panel not matching with the pattern (2%), molding not fit to molding hat (4.8%), incorrect grain lines (1.2%). Therefore, the highest defects percentage occurred in Cutting and Molding process is due molding unfit with the hat.

Defects occurred in Production Process is due to the bonding removal (3%), wing fusing errors (4%), stain marks (0.3%), cut damage (0.3%), glue marks (1.5%), snagging (0.3%), wing height uneven (0.5%). It reveals that the majority of the defects occurred due to glue marks. In AQL Process defects occurred highlighted as glue marks (3%), C/F un balanced (1.7%), missing bar tack (0.3%). It is clearly visible among three processes of consideration Soma Style 1's Production Process contains the highest percentage of defects.

4.3 GAP Style (i)

Value Stream Map of the center front component of a garment of Gap style (1), can be expressed as follows

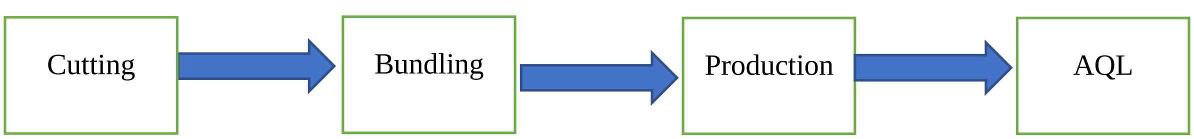

Figure 4.6 VSM of Gap Center Front component

Value Stream Map for the wing component of the garment is as follows.

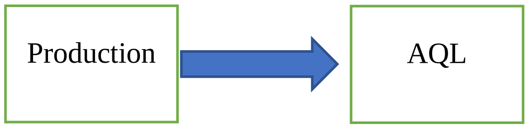

Figure 4.7 VSM of Gap Wing component

The cup component of the garment can be represented by a Value Stream Map as follows.

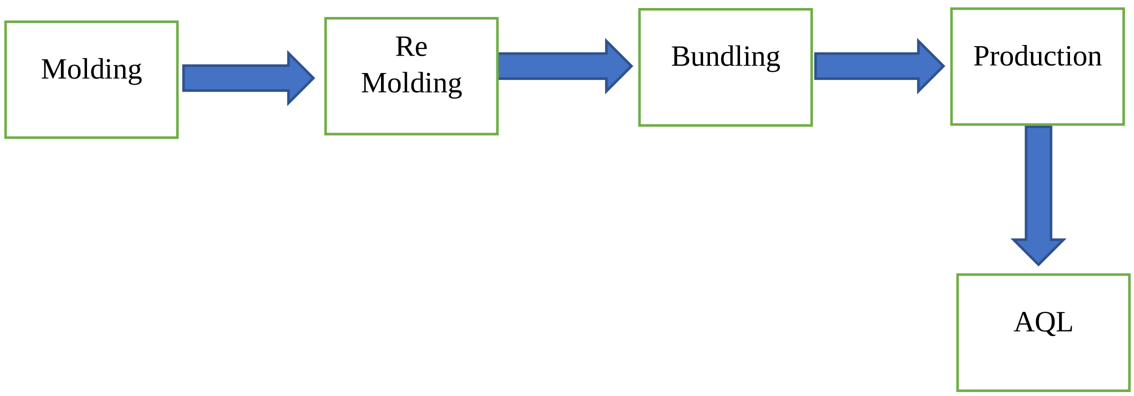

Figure 4.8 VSM of Gap Cup component

Defects percentage reported in considered processes of GAP style 1 is as follows,

Table 4.3 Defects percentage of Gap style 1

Process	**Defects**
Cutting and molding	8%
Production	11%
AQL	3%

According to the study undertaken, for Gap Style (1) process wise defects occurred can be expressed as follows.

In Cutting and Molding Process defects occurred due to C/F panel not matching with the pattern (4%), molding doesn't fit with molding hat (2%), incorrect grain lines (2%). Which indicates that pattern deviation is the cause for occurrence of highest number of defects.

In Production Process defects occurred due to stain marks (0.6%), wing panels aren't matching to pattern (5%), cut damage (0.3%), cup sheering (3%), snagging (0.3%), wing height uneven (1.3%), measurements high/low (0.3%).

In AQL Process defects occurred due to uncut thread ends (1%) and measurement issues (2%) which is the highest in AQL process. Therefore, it emphasizes that Production Process consists highest percentage of defects comparative to other processes, which needs to study further.

4.4 Calvin Klein Style (i)

Value Stream Map for center front, wing and cup components of the garment, can be expressed as follows.

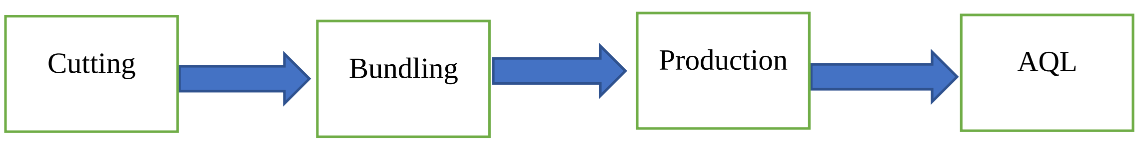

Figure 4.9 VSM of CK center front, wing and cup component

Defects occurred in processes of consideration of CK style 1 is as follows.

Table 4.4 Defects percentage of CK style 1

Process	**Defects**
Cutting and molding	8%
Production	11%
AQL	3%

As per the study, defects occurred in three processes of consideration of customer CK style (1) can be expressed as follows.

In Cutting and Molding Process defects occurred due to panel not matching with the pattern (5%), incorrect grain lines (3%). Accordingly, the highest defect percentage occurred in Cutting and Molding Process is due to panels not matching with the pattern.

Production Process consists highest number of defects compared to other processes of consideration. Defects occurred in the Production Value Stream is due to stain marks (2.5%), cut damage (1.5%), cup sheering (0.5%), snagging (0.5%), wing height uneven (0.5%), measurements high/low (5.5%). In AQL Process defects occurred due to uncut thread ends (0.5%), measurement issues (2.5%) which is the highest cause for occurrence of defects.

It is clear that Production Process consists more defects compared to other processes. Therefore, it is clear that Production Process needs to review thoroughly to overcome problems.

4.5 Amazon Style (i)

The Value Stream Maps of Center front, Wing and Cup components can be represented as follows

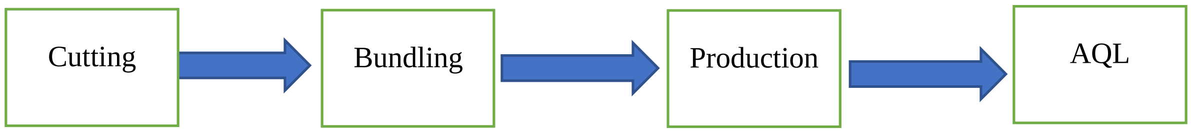

Figure 4.10 VSM of Amazon center front, wing and cup components

Process wise defects occurred for Amazon style 1 can be illustrated as follows.

Table 4.5 Defects Percentage of Amazon style 1

Process	Defects
Cutting and molding	5%
Production	14%
AQL	5%

According to the above table, defects occurred and causes for occurrence can be explained as follows.

The only type of defects occurred in Cutting and Molding process is due to panels not matching with the pattern. Which is 5%.Defects occurred in Production Process is due to seam allowance not followed (9%), stain marks (1%), cup sheering (3%), measurements high/low (1%).

In AQL process defects opted for the reason of measurement high/low (2%), incorrectly packing (3%). The highest defect percentage occurred due to incorrectly packing. Production Process contains highest defect percentage than the other processes of consideration. Therefore, it needs to scrutinize thoroughly to rectify causes of defects occurrence.

4.6 Amante Style (i)

For the center front and wing components of the garment of Amante style (1), Value Stream flow can be expressed as follows.

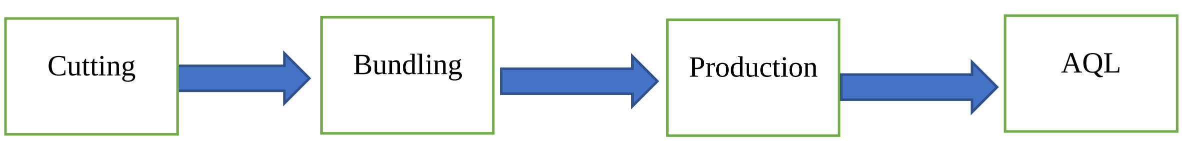

Figure 4.11 VSM of Amante center front and wing components

Following is a representation of a Value Stream Map for the cup components of the garment

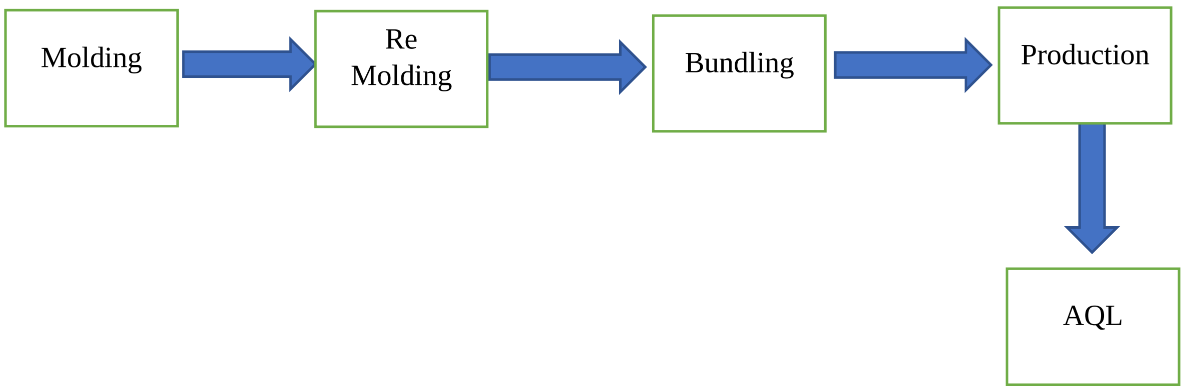

Figure 4.12 VSM of Amante cup component

Percentage of defects occurred in the process of consideration for Amante style 1 can represent as follows.

Table 4.6 Defects percentage of Amante style 1

Process	**Defects**
Cutting and molding	7%
Production	10%
AQL	5%

According to the study carried out process wise defects occurred and the reasons can be represented as follows.

In Cutting and Molding Process defects occurred due to panel not matching with the pattern (2%), color shades (3%), molding not fit in the hat (1%), molding burn (1%). Color shading is the key reason for occurrence of the highest defect percentage in Cutting and Molding process. Defects occurred in Production Process is due to the wing height uneven (3%), thread breakage (5%), missing bar tack (0.3%), cup sheering (0.3%), measurements high/low (0.3%), bra wire mix-up (1%).

Defects opted in AQL Process is due to measurement high/low (1%), uncut threads (1%), thread breakage (3%) where thread breakage is the cause for occurrence of the highest number of defects in AQL Process. Thus Production Process consists highest defect percentage than the other two processes of consideration, it needs to analyze thoroughly.

4.7 Athleta Style(i)

Athleta style 1's Center front, Cup and Wing components of a garment can be expressed in a Value Stream Map as follows,

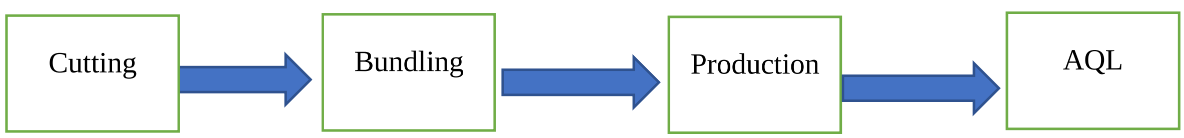

Figure 4.13 VSM of Athleta center front and wing components

Process wise percentage of defects occurred for Athleta style I can expressed as follows.

Table 4.7 Defects percentage of Athleta style 1

Process	Defects
Cutting and molding	7%
Production	11%
AQL	4%

According to the data represented in table 4.7 , defects occurred can be expressed in following manner.

Defects occurred in Cutting and Molding Process is due to panel not matching with the pattern (2%), color shades (5%). It reveals highest defect percentage occurred for the reason of color shading.

In Production Process defects occurred for the reasons of wing height uneven (1%), stain marks (2%), uncut threads (2%), color shades (5%), measurements high/low (1%). Defects opted in AQL process is due to color shades (3%), measurement high/lows (1%). The highest defect percentage occurred in AQL Process is due to color shading.

According to the data, it can reveal that Production Process contains the highest number of defects which needs to study deeply to discover and rectify causes of defects. It clearly depicts that Production Process consists higher percentage of defects for all customers. Therefore, the study focused on Production Processes to identify the causes for the occurrence of defects and to rectify them. Thereby improve the quality level of the process.

4.8 Victoria Secret Style (1) Production Process

VS style 1 is running in 10 production modules. Line wise AQL (Acceptable Quality Level) percentages were tested using Control Charts to verify whether the quality level of 10 production lines is Statistically In Control or there's any variation from the Control Limits. The results obtained can be expressed as follows.

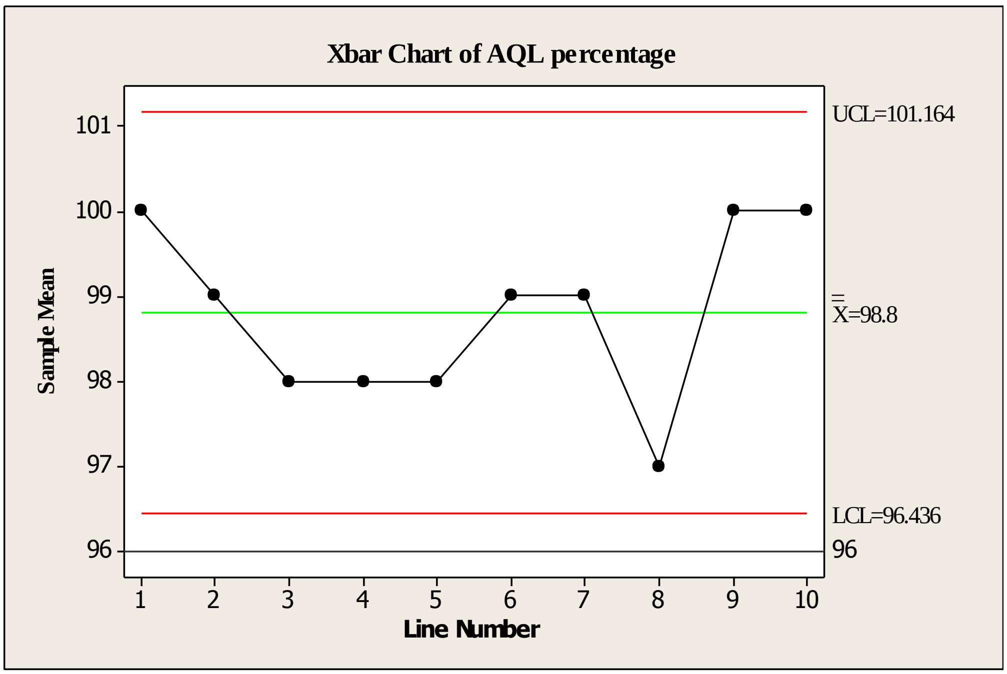

Figure 4.14 Control Chart for VS style 1 Production Process

According to the above graph , all production lines are Statistically in Control. Line number 3,4,5 and line no 8 's quality percentages are lower than the Mean Control Limit. Out of four production lines considered, line number 8's quality rate is the lowest. Plant's required AQL level is 96. Thus, chosen processes related to this line (chosen processes are cutting /molding, production and AQL process) were deeply examined and identified actions need to overcome such quality related matters.

Acceptance Sampling Test was carried out to check the Statistical capability of the processes. Average daily output per production line is about 450 garments. In order to obtain accurate results, sample size for the study was chosen as 100, which is the 22% of line output. (According to the Pareto's rule, 80% of defects occurred due to 20% of causes. Thus, to identify 80% defects 20% of the population was chosen. In order to round off sample size, 100 garments were used as the sample size).

During the Acceptance Sampling Test carried out in Molding Process of line number 8's, out of 100 consecutive molding panels, none of the panels were identified to be defects. Which concludes the Molding Process of VS 1 is Statistically Capable.

100 consecutive Cutting Panels, for line no 8 also analyzed using the same methodology. Since there's no variation (0 defects occurred) in the actual quality level against the expected quality level, it can conclude that the Cutting Process of line no 8 is also Statistically Capable. Same results obtained during the test conducted in AQL process on line number 8.

The same study was carried out in the Production Process of line no 8's. Results obtained there in can be expressed as follows.

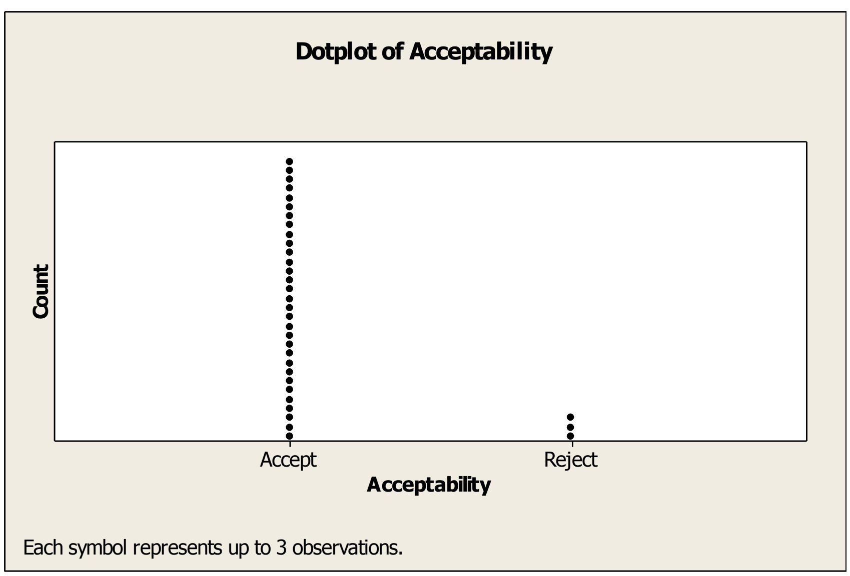

Figure 4.15 Attribute Chart for Production Process VS1 line 8

Above figure represents the acceptability of line output line number 8's. There are 8 occurrences of defects due to stain marks (2), glue marks (2), and uncut thread ends (4).

Since the Actual Quality Level has been deviated from the Accepted Quality Level (which should be 0 defects occurrence according to the plant standard), it can conclude that the process is not Statistically Capable. Therefore, study further elaborated to identify the causes for the occurrence of defects.

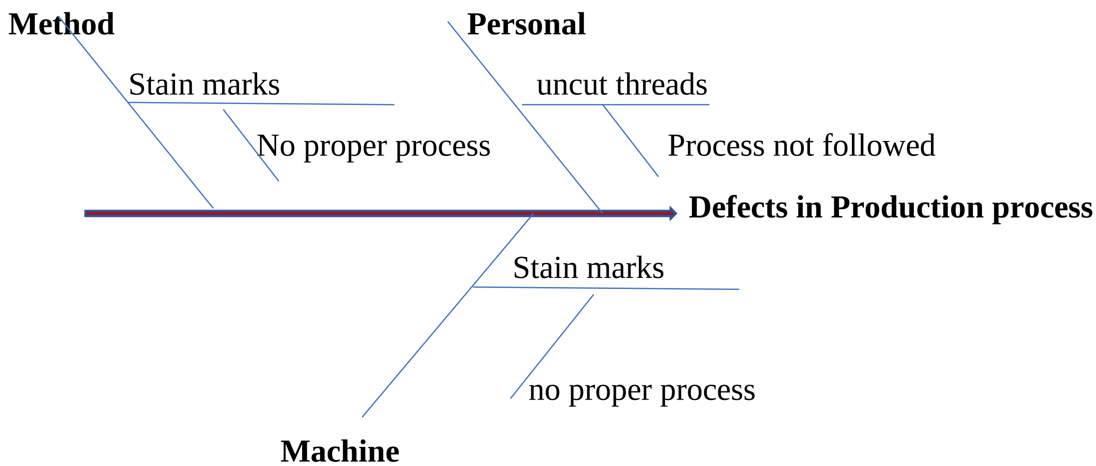

Figure 4.16 Fishbone Diagram for causes of defects for VS style 1 line 8

Causes for the occurrence of defects were categorized according the responsible parties. This is beneficial in identifying improvement opportunities, so to prevent in recurring possibilities.

Uncut thread- a cause due to human negligence. There exists a process that each Team Member should trim the thread ends at their point of stich, which also inbuilt time values with the operating times. Since existing process is violated this matter addressed with the support of Team Leaders, Group Leaders and Value Stream Managers. Disciplinary actions were taken for the Team Members who neglects the trimming.

Stain marks occurred due to machine conditions. Root causes for the occurrence of defects were identified using 5 Y problem solving methodology.

Problem- oil leakage of machines

Why- Machines are not up to the required standard (the factory standard is to provide ‘like new condition’ machine during a style changeover)

Why- There’s no process inbuilt to satisfy the requirement- Therefore need to implement a process

Though a machines service center available, machines are being serviced, there’s no proper process available to ensure that the machines provided during a changeover fulfill the requirement. Therefore, a process is implemented.

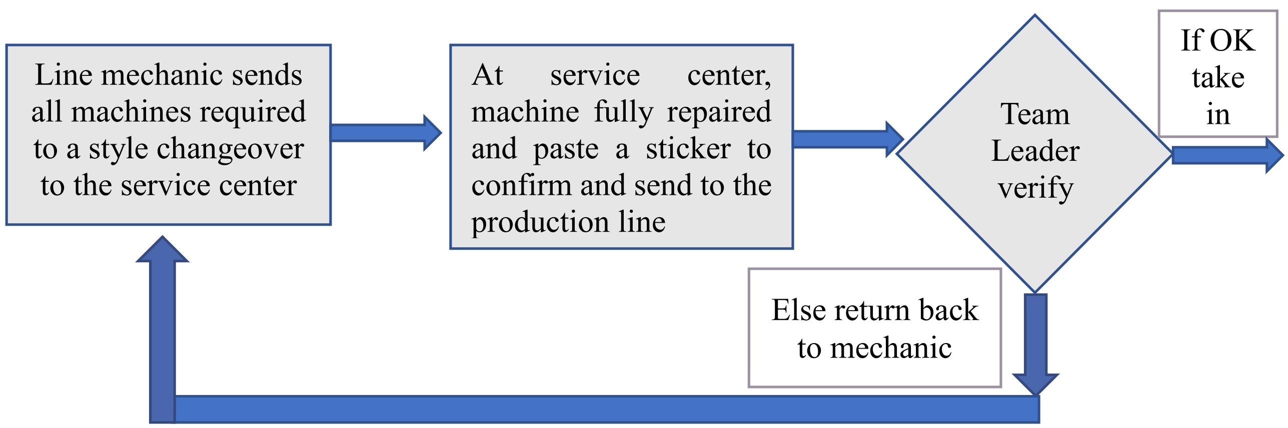

Figure 4.17 Process 1 Flow Chart

After Line mechanic identified machines required for a style changeover, those machines should be sent to the service center (During every changeover the machines provided to the production line should be of ‘like new condition’). After the service a specific sticker is pasted on the machine (Sticker is introduced). In the production line Team Leaders should ensure that they received machines with the service sticker or else they should return the machines.

Glue Marks were occurring due to a method issue. Using 5 Y problem solving methods, it identified the root cause for the occurrence of the problem,

Problem- Appearing glue marks of the cup

Why- Incorrect placement of outer cup panel on the foam cup panel at the beginning. In order to rectify mistakes Team Member readjust the outer panel, but then the mark of first placement appears

Why-Team member doesn't understand the method of panel placement

Therefore, with the support of the technical team, Team Member was re trained for the panel placement.

When studying the problem, it identified even the standard work sheets (STW) are available for each Team Member, Team Leader is not using the Standard Work Sheet for problem solving. Therefore, Team Leader STW auditing process was introduced.

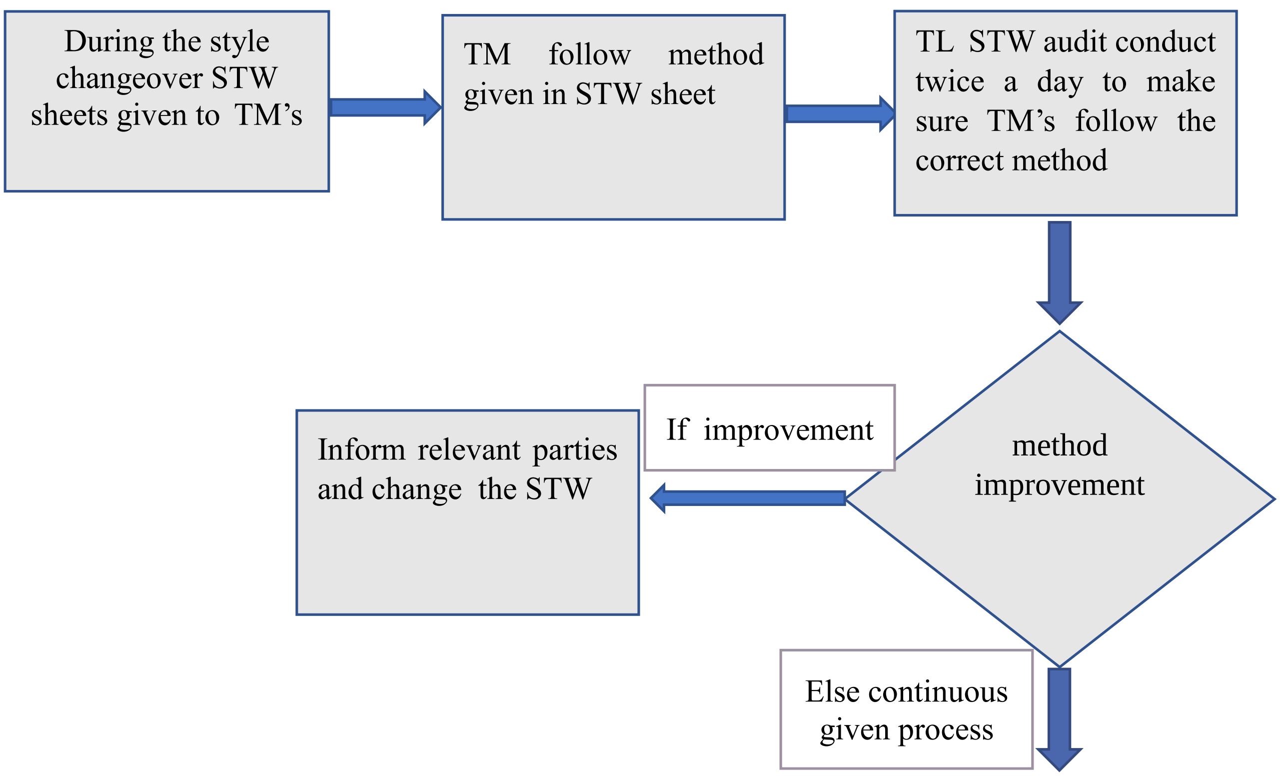

Figure 4.18 Process 2 Flow Chart

In a STW best agreed upon method to perform any operation is given. According to the newly implemented process, Team Leader should ensure whether the Team Members are following the exact method given in STW. If not, the Team Leader should correct the Team Member. If there's any improvement or a change need to be done on STW sheet, Team Leader should inform it to the Technical Department and corrected STW should be provided to the Team Member.

After implementing the process, again Acceptance Sampling test has been carried out. 100 consecutive garments were used for the test, the results concluded that the Production Process is Statistically In Control as well as Capable.

4.9 Soma Style (1) Production Process

It is clearly visible that among the processes of consideration Soma Style 1's Production Process consists of highest defects percentage. Thus, Production Process deeply analyzed using Statistical and Lean methodologies to rectify the errors occurred. There are 7 production lines running Soma Style 1. Line wise AQL percentages of Soma style (1) is expressed as follows.

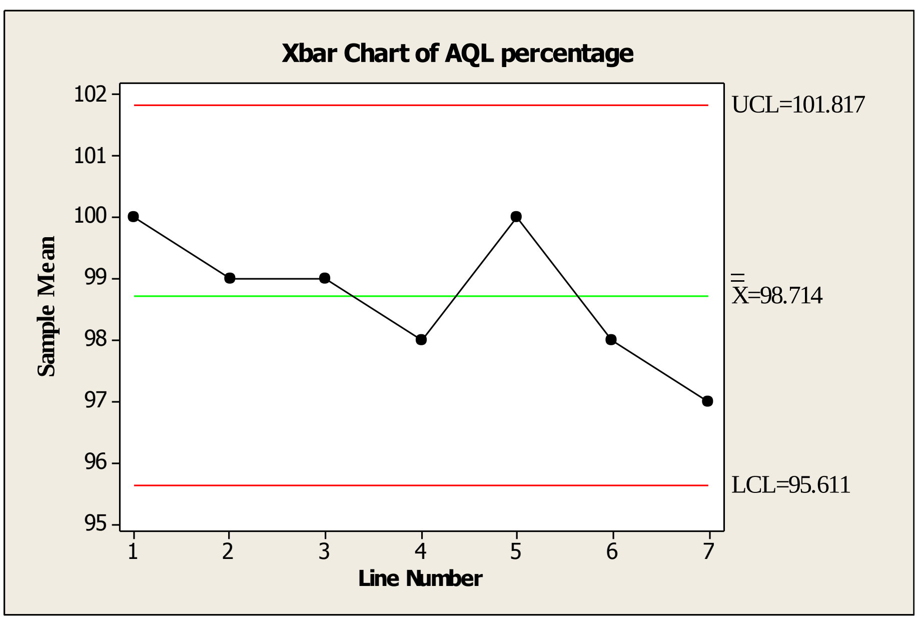

Figure 4.19 Control Chart for Soma style 1 Production Process

According to the above graph it is visible that quality levels of line 4,6 and 7 are lower than the Mean Control Limit. Though all lines exceed the Lower Control Limit, line 7 shows the Lowest Quality Level. Therefore, processes of line no 7 thoroughly studied to identify the origin of defects.

An Acceptance Sampling Test was carried out to inspect sample size of 100 consecutive garments in Cutting and Molding processes. All the garments used during the test were accepted. This leads to conclude that Cutting and Molding process is Statistically Capable. Since Actual Quality Level doesn't deviate from the Required Quality Level it can conclude process is Statistically in Control. During the study conducted in AQL process , out of 100 garments of consideration, 0 defects occurred. Therefore, it can conclude that the process is Statistically Capable and in Control.

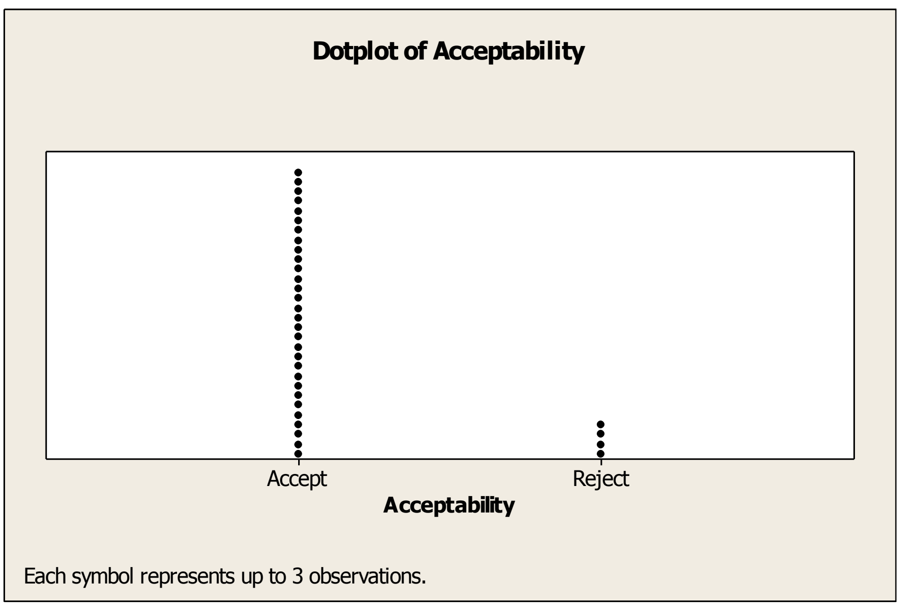

Figure 4.20 Attribute Chart for Production Process Soma 1 line 7

Above figure represented test result obtained during the Acceptance Sampling Test carried out in line number 7's Production process . Chosen sample size was 100 garments. Non-acceptance occurrences were due to 6 garments for stain marks, 5 garments for uncut thread ends and 1 garment for channeling code uneven.

A depth analysis carried out to discover the reasons for the occurrence of defects. The results obtained can be illustrated as follows.

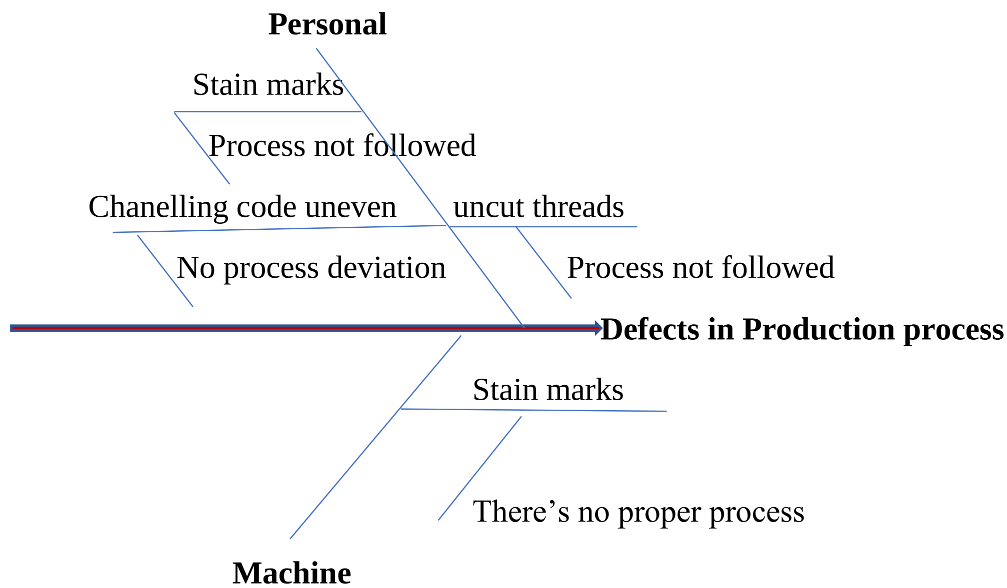

Figure 4.21 Fishbone Diagram for causes of defects for Soma style 1 line 7

Defects were categorized according to the responsible parties. This is illustrated in the above figure. Root causes for occurrences of defects were identified using 5 Y problem solving methodology.

Stain marks occurred due to Human negligence as well as due to machine problems. Human negligence was addressed with the support of Team Leaders, Group Leaders and Value Stream Managers. A 5 Y analysis carried out to identify the root causes for the above matters. The results obtained can be represented as follows.

Problem-Stain marks occurring in the garment

Why-Stain marks occurred from the pencil, uses to mark hourly target

Why-Garments placed on the pencil, makes marks

***Why* –** Even the placement for garments is defined Team Members does not follow the process

Problem-Stain marks occurring in the garment

Why- A machines make a corrosion mark on the garment and mechanic doesn't noticing

Why **–**Team Member hasn't communicated the defect to the mechanic

Why **–**There's no proper communication channel

According to the factory standard machines used for stitching should be of 'like new condition'. According to the analysis, it was able to identify the importance of implementing a proper communication channel to inform the machine conditions.

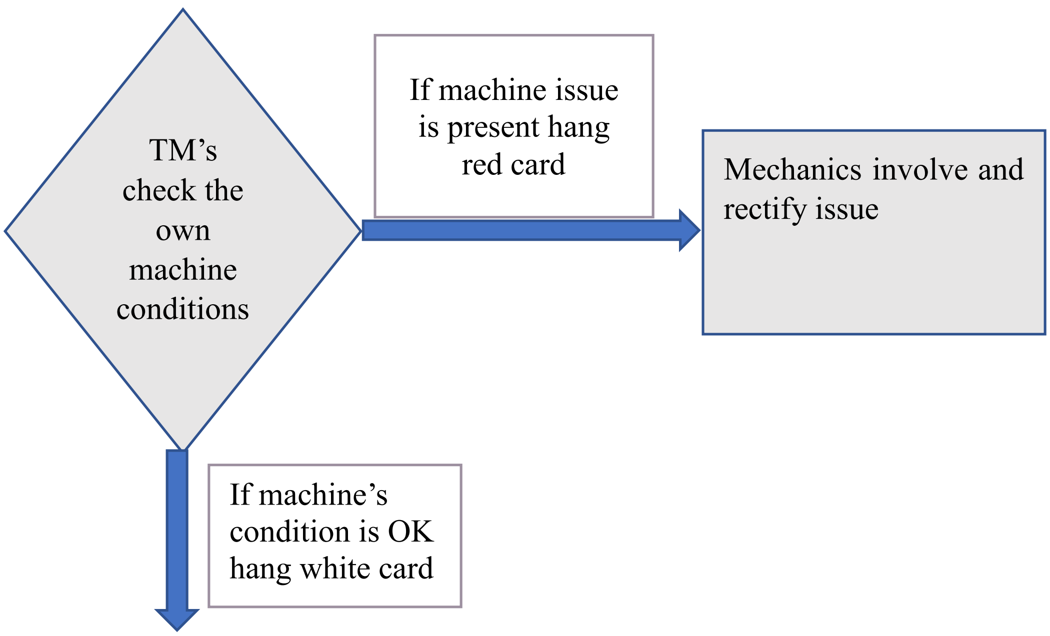

Figure 4.22 Process 3 Flow Chart

Team members spend most of their time with machines. Therefore, they know the condition of their machine than a mechanic .TM's are capable to identify even a minor machine defect. In order to fulfill a communication requirement, a process has to be established. A card system was introduced for Team Members. There are two types of cards, namely red card and white card. Red card is used when there is a minor problem with the machine and white card used when the machine condition functions correctly. Team Members hang the card according to the condition of the machine. Machines hanging red cards, mechanics get involved and rectify the problem. This reduces the occurrences of major breakdowns, occurrence of defects as well as ensure the conditions of the machine.

Channeling code uneven was due to Team Member's inability to follow checking process of garments (the process is to check the garment before passing them to the front of the line). Using 5 y problem solving methodology it identified the root cause for deviation of the process.

Problem-Unable to follow checking process
Why-Team member doesn't have sufficient time to check the garment (team member doesn't perform within the given time)
Why- A new team member, skill level is not sufficient.

Therefore, with the aid of a Yamazumi another Team Member (who is not fully utilized) balanced to support this new Team Member for de- chaining part of the operation. After the changes, Production Process again re checked for 100 consecutive garments. Since 0 defects occurred, it can conclude that the Production Process is Statistically Capable.

4.10 Gap Style (1) Production Process

Gap style 1 is running in 7 production lines. Line wise AQL percentages alongside with line numbers can be represented in a graphical form as follows.

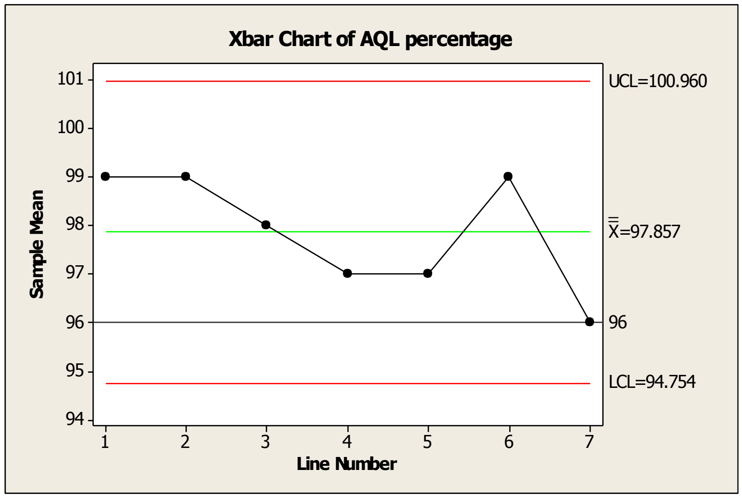

Figure 4.23 Control Chart for Soma style 1 Production Process

According to the above graph quality levels of line 4 ,5and 7 lies below the Mean Quality Level. Line number 7, out of 7 Gap style 1 production lines shows lowest AQL percentage. Therefore, it has been decided to study thoroughly Value Stream of this line.

During the study conducted at Cutting and Molding Process of GAP style 1's , the result was to accept all panels. There were no defects. 100 consecutive panels were used for the study. Since the actual quality level doesn't deviate from required level, it can conclude that this process for GAP customer 1 is Statistically Capable so do Statistically in Control. Similar results obtained from the study conducted in AQL Process.

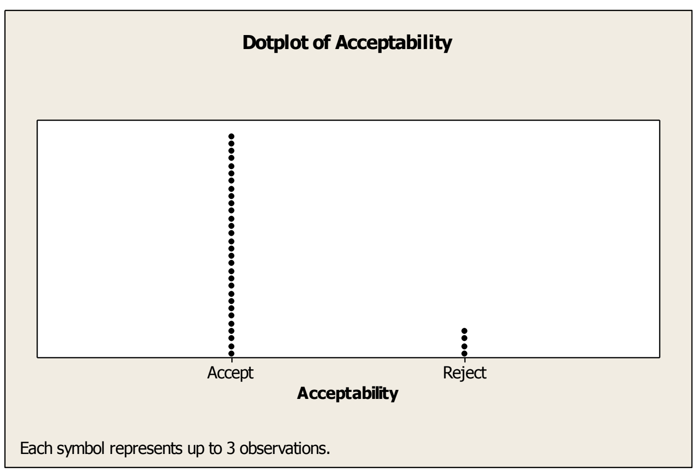

Figure 4.24 Attribute Chart for Production Process Gap style1 line 7

The same Acceptance Sampling test was carried out for Gap Style 1 Production process. During the test there are 10 incidents recorded for deviations from the standard, due to various causes. 5 garments for wing height uneven. 3 for uncut threads and 2 for snagging.

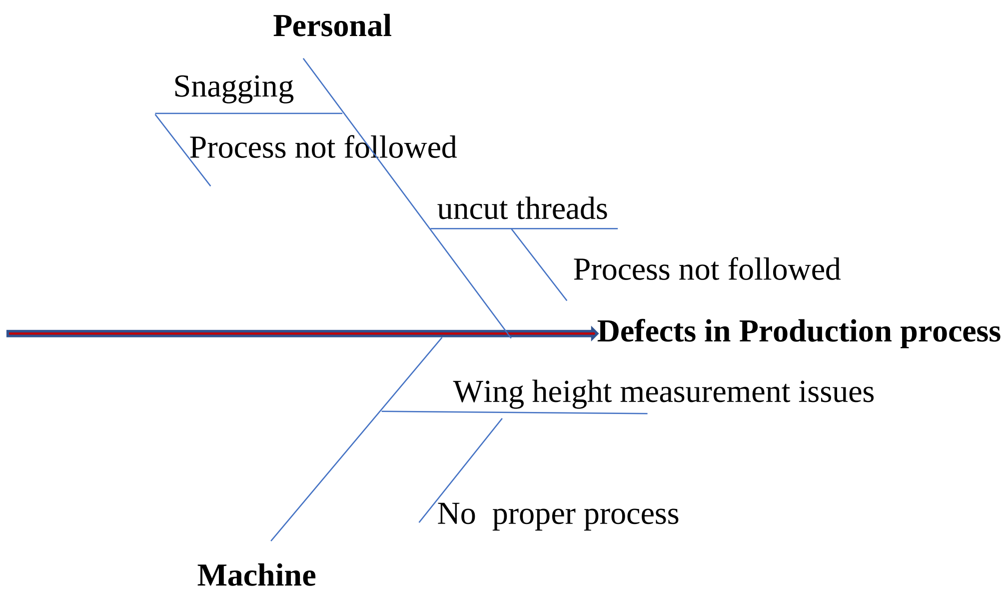

Figure 4.25 Fishbone Diagram for causes of defects for Gap style 1 line 7

Type of defects and causes, categorized according the responsible parties which represented in above Fishbone Diagram. It clearly visualizes rectification opportunities as well.

Uncut thread occurred due to human negligence, the issue was addressed by similar methodology used in Victoria's Secret line. Snagging was occurred due to violation of a given process. It had been advised to use gloves since the fabric can snag easily. Therefore, process violation was addressed with Team Leader, Group Leader and Value Stream Managers.

To identify reasons for the wing height measurement issue, 5 Y problem solving methodology was used.

Problem- Wing height measurement issue

Why- Wing height measurement is higher than the required level

Why- Elastic doesn't gauge in large sizes in bottom elastic attach operation

Why- Elastic tangled from front end in large sizes

This problem was rectified with involvement of Mechanic Team. This defect could have been identified by the process of STW audit implemented in. Therefore, all Team Leaders, Group Leaders were encouraged to conduct STW audit.

After the process improvement, process was re-examined using the similar test. Defects occurred is marked as 0 for consecutive 100 garments which supports the claim that the process is Statistically Capable. Again, the process is Statistically in Control.

During the study conducted for AQL process of Gap style 1 line no 7, out of 100 consecutive garments of consideration, 0 defects occurred. Therefore, it can conclude that the process is Statistically Capable and in Control.

4.11 CK Style (1) Production Process

Calvin Klein style 1 is running in 7 production modules. Since Production Process of CK style 1 is identified to consists highest number of defects from above studies, it is thoroughly analyzed.

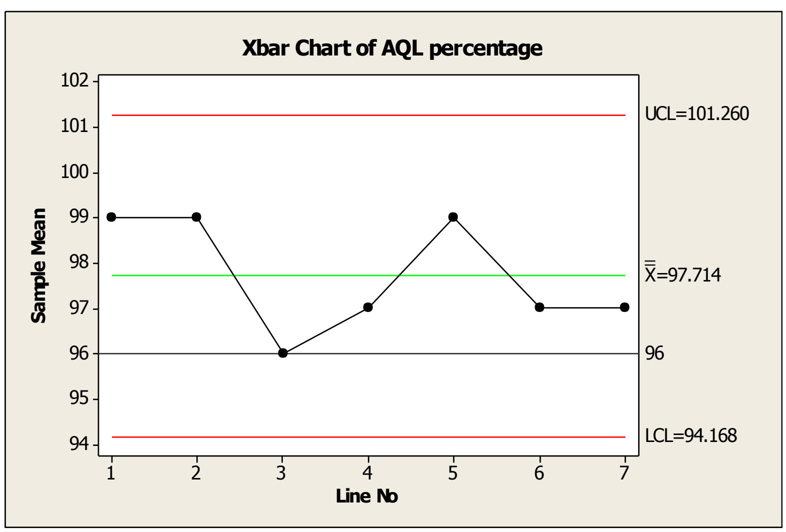

Figure 4.26 Control Chart for CK style 1 Production Process

As per above graph, quality levels of line 3, 4, 6 and 7 needs to improve. Since line number 3's AQL value is minimal than the other modules, all processes contributed in creation of this line decided to investigate thoroughly.

According to the study, Line no 3 of CK style1, Cutting Process and AQL Processes were analyzed using Acceptance Sampling test as mentioned earlier. Since 0 defects occurred, it can claim that process is Statistically Capable as well as in Control.

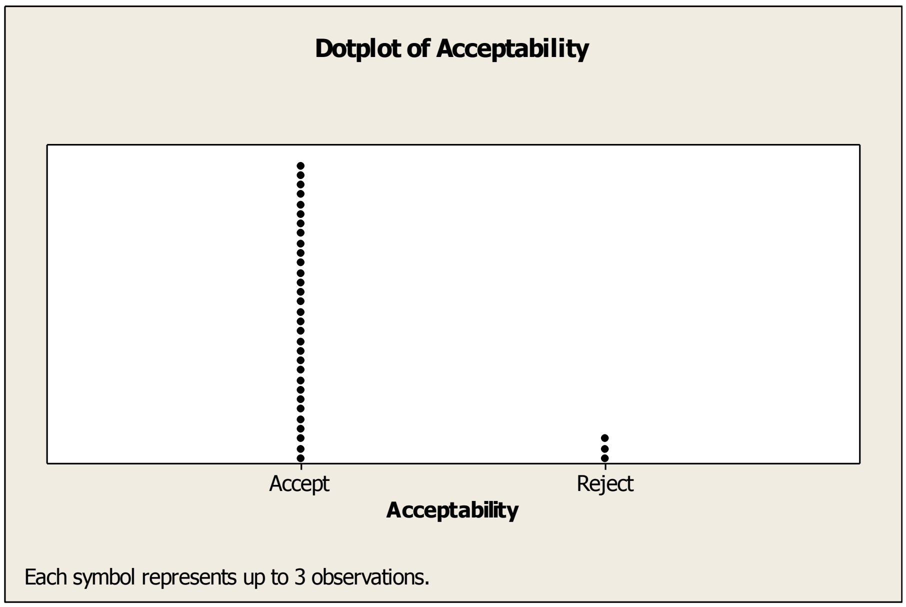

Figure 4.27 Attribute Chart for Production Process CK 1 line 3

Figure 4.22 visualized Acceptance and Rejection status of CK style 1 line no 3's 100 consecutive garments of Production Process. 8 of defects were identified during the study. 4 garments for cup sheering and 4 garments for measurement deviations.

In order to identify root causes for the defects a Fishbone diagram was used.

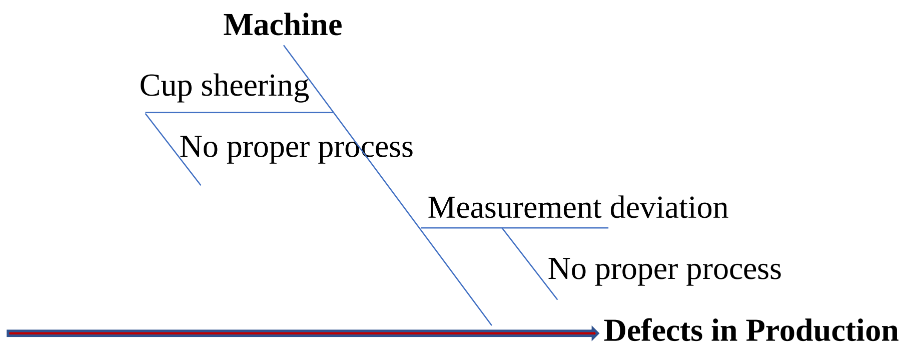

Figure 4.28 Fishbone diagram for causes of defects for CK style 1 line 3

5y problem solving methodology was used to identify causes of the defects.

Cup sheering occurred due to the stabilizer tightening. According to 5 Y analysis, origin of the problem can be expressed as follows.

Problem- Cup sheering
Why-Stabilizer tightening
Why-Stabilizer does not smoothly flow through Foot
Why- Rust particles are under foot creates friction
Why- Machines need to serviced properly

It concluded that 'like new conditioned' machines were not provided to the line during the style changeover. Therefore, the process established in VS line implemented in the entire plant.

Measurement deviation also occurred due to machine conditions. Therefore, it is clearly visible that establishing the process ' like new condition' machines providing to the lines, which is also recommended above.

After rectifying defects, occurrence of defects were checked using Acceptance Sampling Test. Defects occurred was 0.Which provides evidence to conclude that the process is Statistically Capable and Controllable.

AQL process of line number 3 analyzed using 100 consecutive garments similar in the other lines to verify its acceptability. Results verified that the process is Statistically Capable. (0 defects occurred).

4.12 Amazon Style (1) Production Process

According to the above analysis Amazon style 1's Production Process consists more defects compared to other processes of consideration. There are four production lines running Amazon Style 1. If line wise AQL levels plot against line numbers, results can be represented as follows.

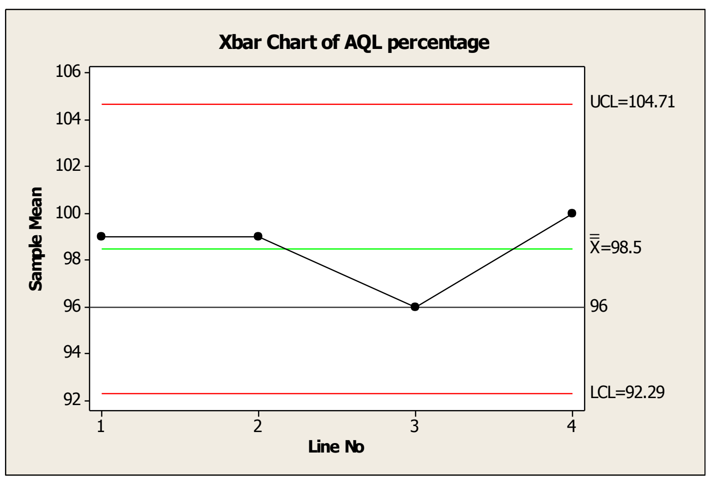

Figure 4.29 Control Chart for Amazon style 1 Production Process

In Amazon style 1 AQL level in line number 3 is minimal than the other lines of consideration. Therefore, processes contribute in constructing line number 3 analyzed thoroughly to identify the origin of defects.

Cutting Process of Amazon Style 1 analyzed using Acceptance Sampling Test .Sample size of consideration is 100. There's no deviation of quality level   from the standard. Therefore it can conclude that Cutting Process is Statistically Capable and Controllable.

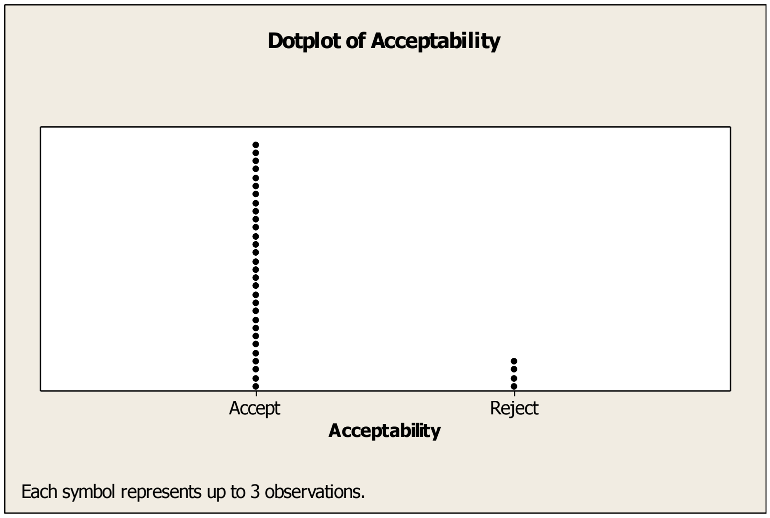

Figure 4.30 Attribute Chart for Production Process Amazon 1 line 3

During the study carried out, 12 defect garments were identified. 8 defects were due to measurement lows, 1 for wing height uneven, 1 defect occurred due to chanelling code uneven ,1 for cup sheering and another 1 for uncut threads.

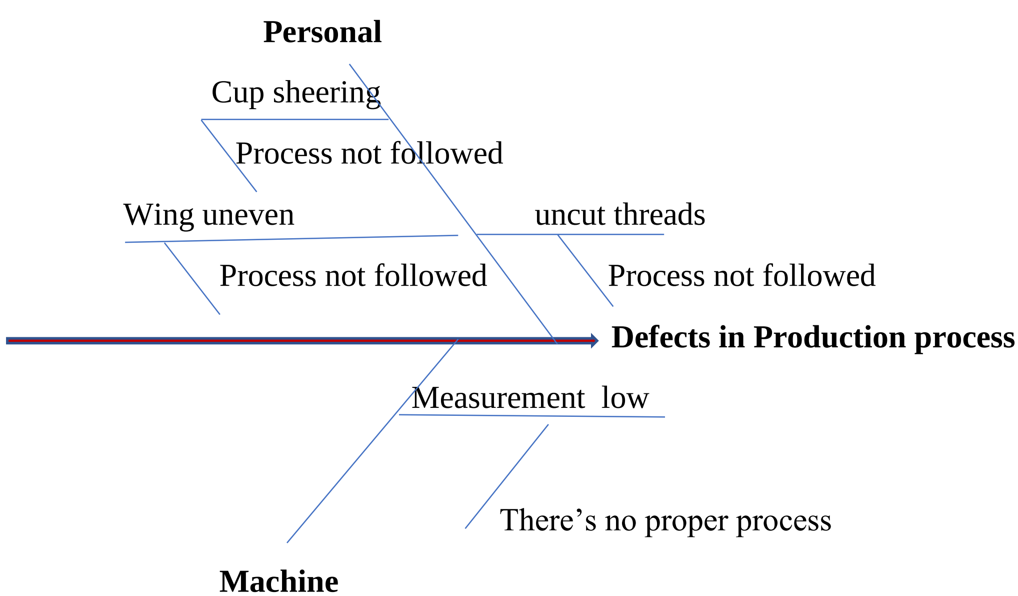

Figure 4.31Fishbone diagram for causes of defects for Amazon style 1 line 3

Figure 4.26 is visualized causes for defects identified during the study. In order to identify root causes of the defects, 5 Y problem solving methodology was used.

Problem- Measurement low in wing
Why- machine feed dogs gathered wing panels
Why- Friction of bearings of feed dogs is higher
Why – Machines need to lubricate

The results denote that machines need to serviced promptly before providing into lines. Thus, it clearly depicts the importance of the process implemented to ensure 'like new condition' machines. This matter could have overcome by lubricating machine feed dogs.

Wing height uneven, chanelling code uneven and cup sheering occurred due to violating the established checking process. This matter solved with the support of Team Leader, Group Leader and Value Stream Managers.

After rectifying the defects, process quality re-checked using Acceptance Sampling methodology. During the study it concluded that the Production Process is Statistically Capable and Controllable after rectification.

The AQL process of line 3 observed using Acceptance Sampling methodology. Since 0 defects occurred during test of 100 consecutive garments, it can conclude that AQL process is Statistically Capable.

4.13 Amante Style (1) Production Process

As it mentioned earlier, defects occurred in Amante style 1's Production Process is higher than the other processes of consideration. Thus, Production Process studied deeply to identify causes for the occurrence of defects. AQL percentages against line no running Amante style 1, can be represented as follows.

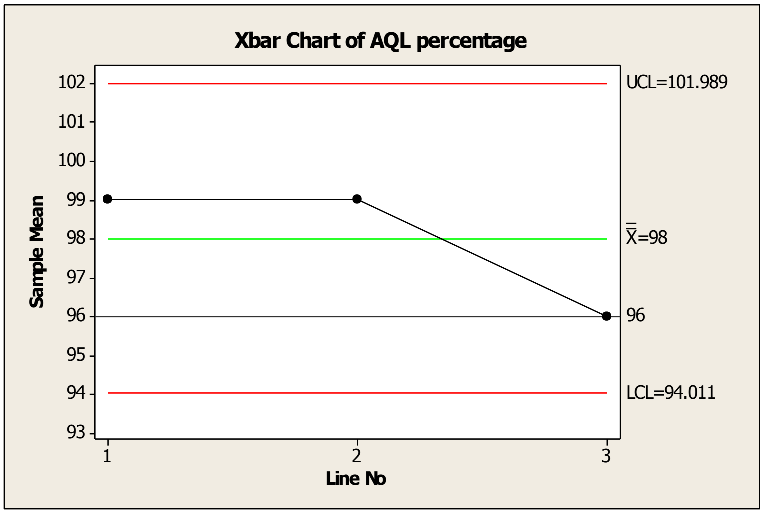

Figure 4.32 Control Chart for Amante style 1 Production Process

According to the above graph quality level of line number 3 is lower than the Mean Control Level. Therefore, all the processes attached to line number 3,were deeply analyzed to detect the origin of defects.

Acceptance Sampling Test conducted in Cutting and Molding process for 100 consecutive garments of Amante style1.Which caused 0 occurrences of quality deviations from the Acceptance Level. Therefore, it can conclude that the Cutting and Molding process of Amante 1 is Statistically Capable and in Control.

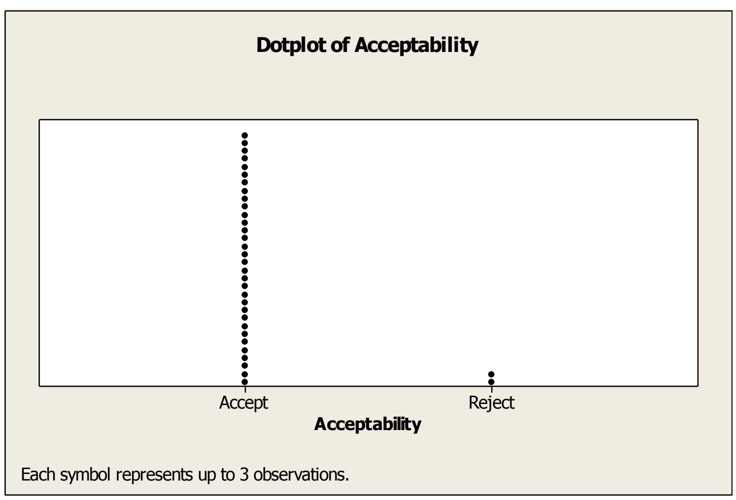

Figure 4.33 Attribute Chart for Production Process Amante 1 line 3

Figure 4.28 is a graphical representation of quality attribute of Amante style 1's Production Process. There are 4 occurrences of deviations from Accepted Quality Level. 100 consecutive garments from the line output were considered for the study. Out of 4 defects occurred, 1 defect occurred cause of snagging while other 3 occurred due to uncut threads.

In order to identify the root cause for the occurrence of defects, data further analyzed. The results obtained can be illustrated as follows.

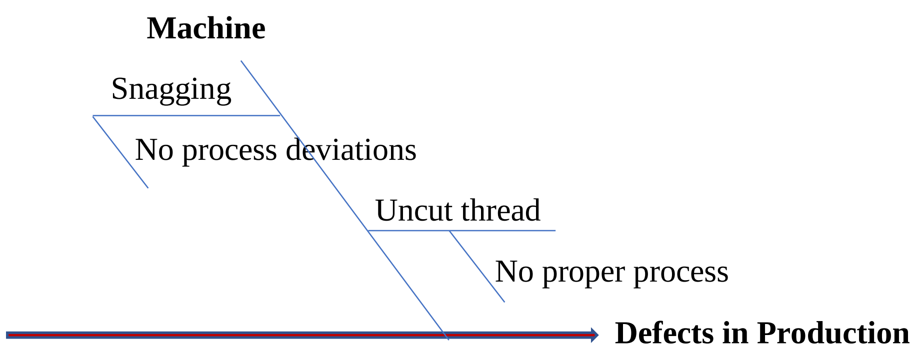

Figure 4.34 Fishbone diagram for causes of defects for Amante style 1 line 3

Causes of the defects classified according to the responsible parties which is visualized in the above fishbone diagram. This provides an insight for improvement opportunities.

Uncut thread occurred due to human negligence. So same solutions provided for VS line provided to this line also.

Snagging was occurring at one point in the production line. There was an attachment used to keep finished garments. It contained an iron bar with a sharp edge. When a Team Member place the garments, it entangles and cause snagging. Therefore, the iron bar has been rectified.

After the changes implemented, the process is re checked for 100 consecutive garments. Since 0 defects occurred, it can conclude that the process has become Statistically Capable and Controllable.

 AQL Process of the production line checked with 100 consecutive garments. Since 0 defects occurred, it can conclude that the process is Statistically Capable.

4.14 Athleta Style (1) Production Process

 Athleta style 1 Production Process consists of defects than other processes. Therefore, the study elaborates to identify and rectify defects. There are six modules run-in the style of consideration.

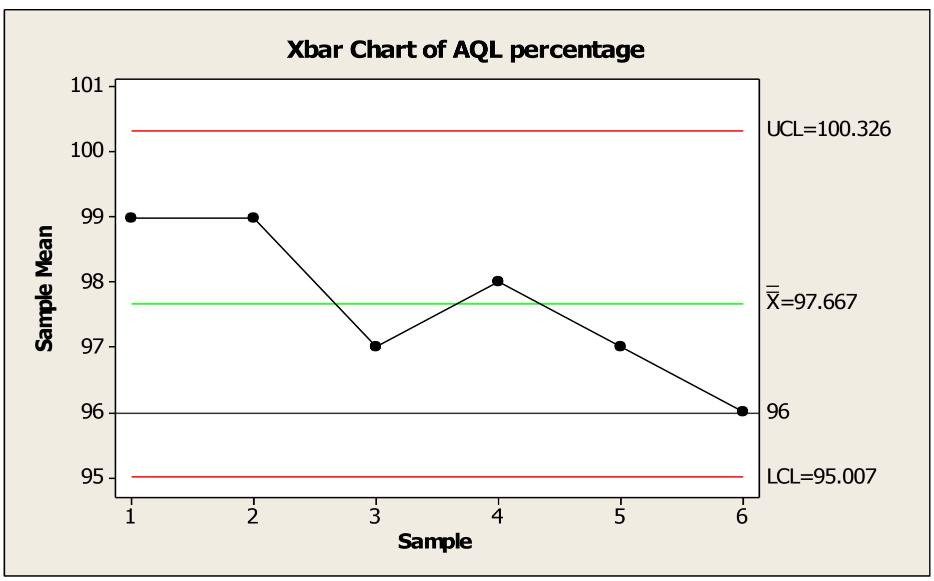

Figure 4.35 Control Chart for Athleta style 1 Production Process

According to above graph line number 3, 5and 6‘s quality levels has minimal value which is also lower than the Mean Quality Level. Since Line no 6’s quality level is lower than that of the other lines, all process belongs to Value Steam has been examined assiduously to rectify origins of the defects.

Athleta style 1 Cutting Process examined using 100 consecutive garments. Since there's no deviation of Actual Quality Level from the Required Quality Level, it can conclude that the process is Statistically Capable.

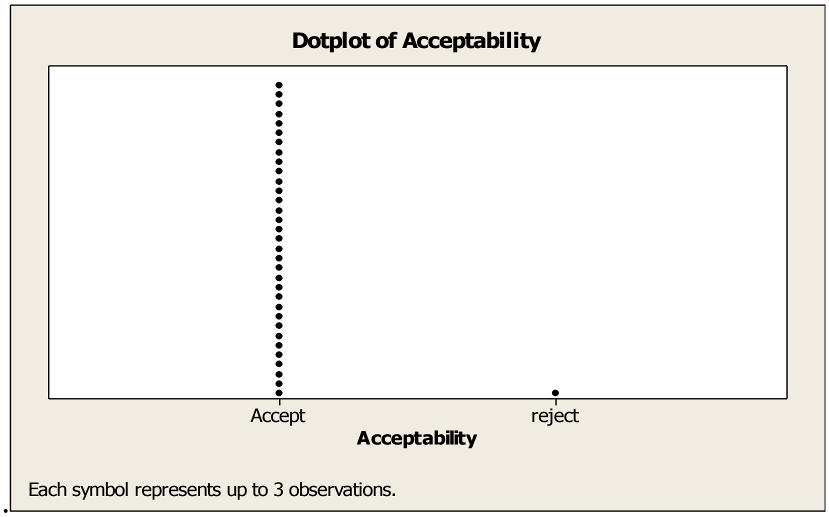

Figure 4.36 Attribute Chart of Production Process Athleta 1 line 6

According to the above graph, only 1 garment has been deviated from the standard quality level of Athleta style 1. It is expected to take action and rectify them by identifying types of defects as well as causes. Therefore, a Fishbone diagram is used to fulfil this requirement.

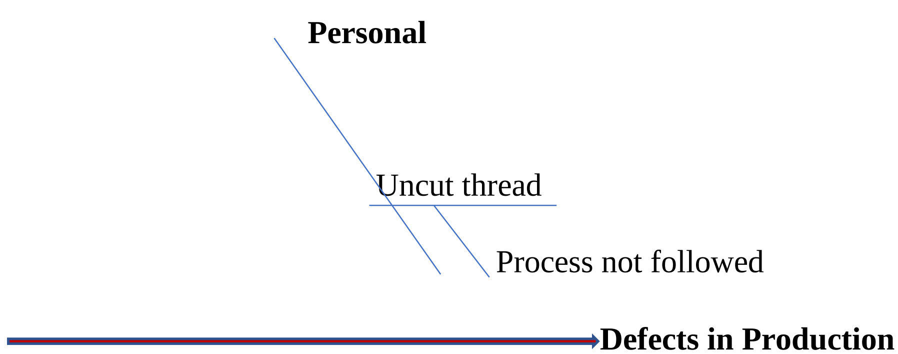

Figure 4.37 Fishbone diagram for causes of defects for Athleta style 1 line 6

Uncut thread occurred due to human negligence. Same solution is provided to VS line has been provided for this line. With the support of Team Leader, Production Executives, Group Leader and Value Stream Managers, same actions were taken.

After the improvements, process was rechecked using Acceptance Sampling Methodology. It was resulted that the process is Statistically Capable and controllable. AQL Process of line number 6 examined for the acceptability by using 100 consecutive garments. Since there's no deviation from Standard Quality Level it can conclude that the process is Statistically Capable and Controllable.

4.15 Determine Sample Size

In order to verify whether the available plant quality process is able to ensure customer quality requirement, the sample size needed to inspect daily has been calculated. According to customers' requirement, plant AQL level need to ensure is 96%.

Method

Parameter	Mean
Distribution	Normal
Standard deviation	1 (estimate)
Confidence level	95%
Confidence interval	Two sided

Results

Margin of error	0.04
Sample Size	2404

From the study it reveals that sample size needs to examine daily is 2404. It can conclude that the plant needs to focus on improving the current sample size. (Current AQL sample size is 1700-1750 per day).

4.16 Process Capability Analysis

According to the findings, it stipulates that all Cutting, Molding and Production Processes are Statistically in Control. (Production Processes of all customers after process improvements became statistically in control).In order to verify Statistically Capability of the plant quality process, a capability analysis has been conducted. AQL data of 100 consecutive days were considered for the study.

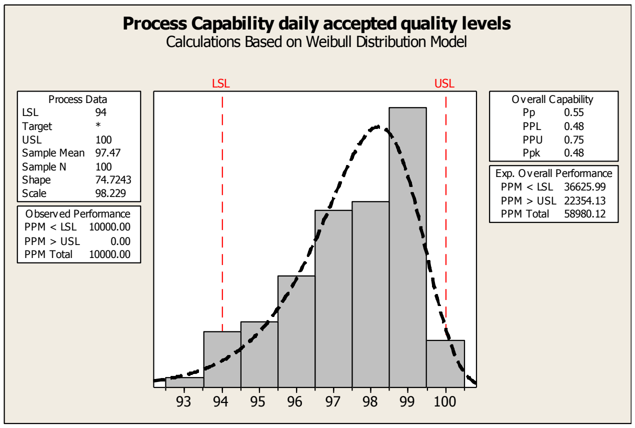

Figure 4.38 Process Capability Analysis chart

According to the results obtained from the study, it reveals that Ppk and Pp values are smaller (0.48 and 0.55 respectively).Therefore, it can conclude that the process is not sufficiently capable (Pp index<1 means the process is not capable).It further can conclude that process spread<tolerance. As well as Ppk=0.48<1.5. Which stengthen the conclusion that the Plant Quality Process is not Statistically Capable.Thus, the entire Plant Quality Process needs to be rectified.

4.16 Outline of the Chapter

Production process of all customers contains highest defect percentages out of 3 main processes of consideration. Therefore, production processes of 7 selected customers studied thoroughly to check Statistical capability and controllability. Using Lean Tools and Statistical Quality control tools origins of defects was identified and rectified.

CHAPTER 5

CONCLUSIONS, RECOMMENDATION & FUTURE WORK

5.1 Conclusions

Ameliorate quality levels in the process of company ‘A‘ which is a giant in apparel manufacturing company in Sri Lanka is a prominent task to be undertaken. ‘A’ company follows Lean Manufacturing System, so all processes in the company aligned with the cited system. Though the company ‘A’ is a prominent bra manufacturer for world renowned brands, study limited for seven main customers, Victoria’s Secret, Soma, Gap, Calvin Klein, Amazon, Amante and Athleta. Out of developed Value Stream Maps, most crucial processes need to study on identified. With the resources and time available for the study Cutting- Molding, Production and AQL Processes were selected.

The study contemplates that overall Cutting /Molding and AQL processes of all customers are statistically in control as well as capable. Production Process of all customers shows lesser AQL percentages compared to other processes of consideration, which stipulated the essentiality of a thorough analysis of Production Processes. Therefore, the study concentrated on Production Processes of mentioned seven customers. Since Production Processes’ quality level is higher than the Lower Control Limit, it concludes that the process is Statistically in Control. By choosing production lines show highest deviations from mean value and analyzed using Lean Manufacturing and Statistical Quality Control tools, root causes of the defects occurred were identified. Thereby required actions were carried out to strengthen the prevailing processes. New processes were implemented which is essential in process quality enhancement.

Results obtained afterwards stipulated that the Production Process also became Statistically Capable. The elaborated analysis explicit the overall quality process of the plant needs modification. Sample size needs to examine daily needs to change. It further reveals that the Plant Quality Process is not capable, which strengthens the claim need of plant Quality Process amendments.

5.2 Recommendations

Throughout the analysis uncut thread identified as a major type of defects occurred in most of the production lines. Therefore, it is recommended to inbuilt thread trimming option for sewing machines.

The process of providing ‘like new machines’ for the production line is established during the analysis. A problem highlighting card system also has been introduced to prevent recurring problems. In order to redeem opportunities for occurrence of future machine related issues, it is recommended to establish a mechanism for machine cleaning. Since dust particles and thread ends can cause machine defects as well as breakdowns, it is important to carry out daily basis machine cleaning. Therefore, machine cleaning standard time can be provided and also encouraged Team Members to clean their machines according to the instructions.

Team Leader Standard work sheet auditing process can be used to support the bottle neck solving. In a STW, standardized time values , which required to perform the considered operations can be provided. Team Leader can check whether the Team Members are performing within the provided time value and make improvements.

5.3 Future Work

The study reveals that the Plant Quality Process in not capable. Similarly, daily examining sample size is inadequate. Therefore, it is recommended for plant management and future researchers to look in to further amendments. Since daily AQL sample size need to improve, it needs to verify whether it can be achieved with available number of AQL auditors. If the number of auditors need to increase, then it needs to look into the impact for the plant direct to indirect cadre as well as the cost factor.

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