Enhancing Process Capability Using DMAIC Approach in Shoe Manufacturing Industry

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Declaration

I hereby certify that this research study is entirely my own work and has been submitted for the partial fulfillment of requirements for the degree of Master of Science in Design & Manufacturing Engineering. I hereby declare that I have exercised reasonable care to ensure that the work is original, and does not to the best of knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Master's Thesis Work

We hereby recommend that the dissertation prepared under our supervision by **Muhammad Amir Habib(NUST201260370MSMME62012F)**, titled**: Enhancing Process capability Using DMAIC Approach in Footwear Industry**be accepted in partial fulfillment of the requirements for the award of **MS Design and Manufacturing Engineering** degree with ___ Grade.

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Principal

Specially To

Maan G (Late)

&

Family

For all the support and love

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Abstract

In this cut throat era where the competition is getting higher between the manufacturing industries dealing in similar kind of business, for any manufacturing organization to stay in the market it must have the ability to deal with shorter lead times & flexibility to deal with customized products. For this, manufacturing industry needs to make the best utilization of available resources & become more productive. The company under study is a leading footwear manufacturer & exporters. In the field of footwear manufacturing where the customization is so high & order quantities are short, manufacturers need to have a flexibility & optimized process to be in the competition. So the company under consideration is having some serious problem in their closing (sewing) section.

This study will focus at root cause analysis for low productivity & high manufacturing cost & resulting in enhancing process capability, developing SOPs for process optimization, implementation & control of SOPs, increasing productivity by 10-15% & reduce manufacturing cost per pair using six sigma DMAIC approach.

1. Introduction

1.1 Research Introduction

Globalization, advanced technology & more customized products have changed the shape of doing the business in a traditional way. In modern era old business models doesn't work. Productivity & flexibility of the manufacturing facility to meet customer's demand are the key factors that plays an important role in growth & improvement of the company.

The objective of this project is to study & evaluate the process of the company, to identify the current situation of company's productivity level & improve the current productivity of the system using six sigma DMAIC methodology. DMAIC methodology will use different tool like statistical & improvement tools.

By using these improvement tools it is possible to increase the productivity of the system to the desired level. This project will be carried out in a shoe manufacturing company to show how the company's productivity can be improved. This project will create an image that can be copied to any type of business. By implementing DMAIC methodology cost, production time & quality will be synchronized.

1.2 Background of Study

Company under consideration is one of the world's largest shoe manufacturers. They produce about 2.5 Million shoes worldwide each year. The production facility consists of 2-Cutting, 20-Closing (sewing) & 10 Lasting lines and this facility produce all types of shoes.

The company wants to be recognized as the best manufacturer of shoe in the world. Therefore the company needs to be more productive & flexible to the customer needs. The focus is to achieve the targets on time & be responsive to the customers' provided order delivery dates. Therefore company is asking to find out the improvement areas which can make the difference in the overall performance of the company.

After production data study & analysis the project team & company's top management have reached to a conclusion that the area which needs the attention & has the maximum ability to improve & grow as compare to other section is **"Closing Section"**.

1.3 Formulation of Study

Now the focus of research will be on to calculate the existing production performance of the closing section & try to find out the potential areas that can respond as per expectation if worked in a proper direction. The project team will be using Six Sigma DMAIC methodology for the overall analysis & improvement steps' implementation.

Using DMAIC methodology project team will analyze the current production performance of the closing line, after that the research will analyze the potential of improvement in the closing lines. By using DMAIC methodology & lean production system team will be analyzing that what impact different lean production system tools can make in improving the productivity. Project team will be focusing over all the possible parameters that can have considerable impact over productivity.

With the implementation of DMAIC methodology to improve productivity & save the cost, project team will also study the new concept of continuous improvement with the implementation of different tools & techniques & how the DMAIC methodology will be practically implemented in any industrial environment.

1.4 Scope of Study

Scope of the project includes the implementation of six sigma DMAIC methodology to identify the process losses & relevant capacity losses to implement different improvement tools that will increase the overall productivity & efficiency of the manufacturing facility.

1.5 Objective of Study

The main objective of the project includes, production system analysis using DMAIC methodology and further accompanied by the following milestones.

- Detailed study of the production process in closing line
- Statistical analysis of line's productivity
- Identification of different factors effecting productivity & efficiency
- Analysis of variances of different processes, Pareto analysis, factorial design for factor effecting analysis.
- Implementation of improvement plan by identifying root cause of low productivity & high manufacturing cost.
- Controlling & monitoring of process for certain time phase.

1.6 Research Benefit

The major benefit of this project is that it will increase the overall productivity of the system with increase in system's flexibility to respond to customer's demand. Other benefits are:

- Training sessions for the workers
- Flexibility to customers' demand
- Improve in efficiency & cost effectiveness
- Minimize the lead time of product
- Economic benefit by cost saving by improving productivity with available resources
- Keep one step ahead of competitor
- Increase customers' confidence to receive the order on time with desired quality level
- Increase team building for achieving the predefined target
- Workers will be trained on multitask

1.7 Area of Application

Industry chosen for the implementation of DMAIC methodology of six sigma is a largest footwear manufacturing industry. The industry is highly equipped with the modern shoe manufacturing & design facility. Company producing variety of shoe under one umbrella. Manufacturing facility of the company consist of 4 main sections

- Cutting Section (Where leather is cut into shoe components)
- Closing Section (Where leather components are stitched together to form top part of the shoe)
- Molding Section (Where sole is made)
- Lasting Section (Where sole is attached with the upper)

Among all the above mentioned sections project team has decided to implement DMAIC methodology in “Closing Section”. Because it’s the section where after detail analysis, project team has found brighter chance of improvement.

1.8 Company Profile

It is the public limited company listed at the stock exchange of Pakistan. It is the biggest footwear manufacturing company of Pakistan & the largest footwear exporters as well. The company employees more than 8000 people. In its manufacturing facility it contains 2 cutting lines, 22 closing lines, 14 lasting lines & 1 molding section. With this complete facility company has the capacity to produce 4000 pairs/day with annual revenue of USD 20 Million from which 45% comes from exports. Company holds a vision to become world Class Company that influences its brand & people. The company holds the mission to be result oriented by continuous improvement in quality, reliability & customer’s acceptance. Focusing to be cost conscious in decision making without compromising the quality. Working to be updated with new introduced technology to optimize the productivity to attain the customers’ attention internationally.

1.9 The Anatomy of “The Shoe”

According to McPhoil (1988) “Shoe can be divided into two main parts,

- Upper
- Lower

Upper consist of the shoe sections i.e. vamp, quarters, toe box, throat, insole board & topline. Lower part of the shoe consist of outsole, shank & heel”.

1.9.1 The Upper of the Shoe

Upper of the shoe is made up of all the parts joining at the portion above the sole of the shoe. All the parts are attached with each other to form a desired shape by stitching together or molded to form a single component. The component of upper are vamp (front of shoe), quarters (sides of shoe), back counter (back part of shoe) & Lining (Inner part of shoe).

Upper part of the shoe can be made of natural or synthetic material. Most of manufacturers have leather as their prime choice because of its ability to pass the air through it that keeps feet a constant temperature. Leather can form the shape of shoe or feet because of its plastic property. Leather can adjust itself according to the area wise pressure of feet & that is why it suits the feet. As far as synthetic material is concerned it doesn’t have that good plastic as compare to leather that’s why it never adjust to foot shape.
Synthetic materials are cheaper & are easy to handle while production process that’s why it has high rate of production. Synthetic material has the ability of water proofing & it is used in shoe along with leather.
Now a day’s cotton corduroy is also used as shoe cover because it is lightweight & have breath able surface.

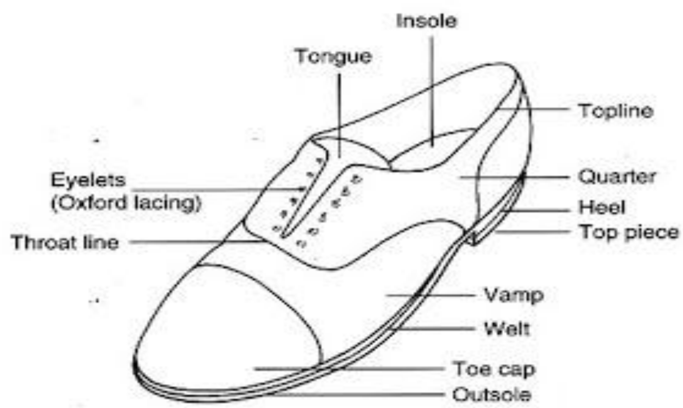


Figure 1Upper of the Shoe

1.9.2 VAMP

Vamp covers the front & top of the shoe. Toe puff is attached to give a strength to front part of shoe & make a desired shape from the front of the shoe. Vamp is not must be of one piece it can be consist of more small decorative components as per design requirement. Vamp are of different patterns as per shoe design requirement.

1.9.3 Quarters

Quarters are those parts of upper covering the sides of the shoe. It is behind vamp. Top of the quarters & back counter when joined form top line of the shoe. This topline is also called as the collar of the shoe.

In close shoes where Oxford style lacing is involved eyelet pieces are attached at upper for lacing. These eyelet pieces are the part of the quarters where as a tongue piece attached under it is the part of vamp. In close shoes where Gibson Style lacing is involved eyelet pieces are attached at upper for lacing. These eyelet pieces are the part of the vamp. Quarters is considered as top in boots. Quarter’s front edges are joined together & covered by back edges in bal type constructions. According to bal method vamp in under the quarters & front edges are not joined together.

For an open to toe shoe there is difference in Blucher’s methodology. In these type of shoe lacing is extended to front part of the vamp. Whereas in athletic shoe vamp & quarters are the single piece component. This one component combination of vamp & quarters have some additive pieces to increase the strength of the toe.

1.9.4 Back Counter

The back part of the shoe is called as back counter. This internal prt of the back counter contain a heel grip to it that strengthen it. Stiffener is used inside back counter to maintain the back counter’s shape as the heel of the foot. Stiffeners are made of different materials i.e. fiberboard or heat molded plastic. The area that a back counter covers depends upon the style requirement. Some type a back counter covers the area to the middle of quarters.

1.9.5 Toe cap

Toe cap is the optional part of the shoe. Sometimes it’s a separate part in the shoe upper & sometimes it’s the vamp covering the whole area. These toe caps are sometimes stitched over the vamp or sometimes completely replaced by decorative components known as toe tips. Toe box is the area in shoe which cover the toe of the shoe. Purpose of toe box is to maintain the toe shape & give comfort toe the foot front part. To specification of the toe box completely depends on the last used to manufacture it. Toe box size varies according to the type of shoe.

1.9.6 Linings

Lining is the inner part of the shoe that provides the durability to the shoe & comfort to the foot. Lining is of different materials i.e. leathers, fabrics & synthetic. Lining which is attached over the inner part of the sole is called sock. Linings are mostly for quarters & insole area & in synthetic material.

1.9.7 Throat

The joining seam of vamp &quarters forms the throat & the seam is known as throat line. It is presented by the joint of vamp's edge with front part of quarters. The placement of throat line depends upon the shoe's design i.e. shoe having vamp shorter than quarters forms a lower throat line. Lower throat line provides wider opening to the foot to enter the shoe. Placement of the throat also varies with the design of the shoe. The throat of the shoe explains the width provided in the shoe. In the shoe with lacing the throat forms at the eyelet, because in these type of shoes vamp & quarters are of single piece.

1.10 The Sole of the Shoe

"Solea" is the term from which "Sole" is derived that means "Soil or Ground".

1.10.1 Insole (inner sole)

It is that part of shoe which is between sole & foot, having the shape of the last. When sole & upper is joined insole provides various methods in which this attachment can be made like toe box lining & welting. It is the separation between sole & upper & a stand where foot can operate. In cemented or Goodyear techniques insole is essential because it make the joint of upper & lower components. Most of the insoles are made up of cellulose & are coated with bacterial preventer material.

1.10.2 Outsole

Outsole is the outermost part of the shoe that is directly exposed to the surface. Outsole is mostly made up of materials like TPR & PU. The sole dimensions thickness, flexibility & width is predefined. Most of manufacturer prefer to make sole with material having properties like water proof, durable & having high coefficient of friction to be less slippery. Synthetic materials are preferred over leather material because it's high gripping potential. Bottom of the sole also have many design. Bottom can be made in many different forms that can increase its ability to grip the surface. Sole are also made with molded cavities in it that reduce its weight. Cavities in the sole are covered with different materials that makes it more flexible. Sole can be made in combination of materials to form desire effect for inner & outer surface of the sole. Mostly the double density sole is formed to create a comfort for inner part of sole & make the outer part tougher.

1.10.3 Shank

Shank is used to support insole & outsole. Shank makes the middle portion of the shoe so stiff that it protects the foot from torsion &flexion. Most type of shoes contain the shank except those which are very flexible & those used for running purpose. In most of the shoe shank is attached in the mid to function like a medial post. It helps the shoe to bend from toe side rather than from middle, as when the heel lift the weight transfer from the back part of the shoe to front part. Shank of the shoe is made in many shapes.

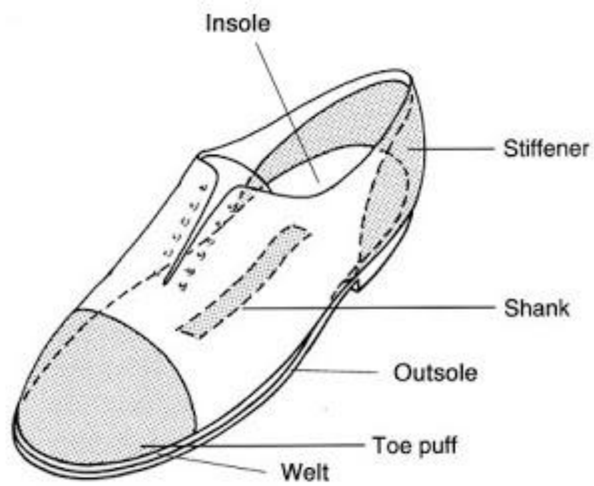


Figure 2Sole of The Shoe

1.10.4 Heel

Heel is the raised part at the back of the shoe. Heel can be formed in different design, heights & material. That part of heel that is attached directly to the sole is called Heel sheet or Heel base & designed to fit the outer heel part. Heel breast presents front face of heel. Part of heel that have direct contact with ground is known as top piece. Heel raise back part of the foot above the ground. There also shoes which are without heel. Negative heel is the one which is lower than the forefoot.

1.10.5 Welt

It is the strip that join sole with upper. Most of the shoe follows this construction in which upper is bounded with sole by welt. Some shoes used stitching for decorative purpose that look likes joining the sole with upper but in actual that is not functional.

2. Literature Review

2.1 Concept of Continuous Improvement

Continuous improvement in Japanese is knows as kaizen, "Kai" means change & "Zen" means better. Key in Japan's competitive success was published in 1986. Term Kaizen explains improvement that takes contribution from both managers & workers & involve relatively little expanse. Kaizen philosophy enforce to apply continuous improvement concept to not only production floor but also to routine life. This philosophy is so obvious to many Japanese that they are unaware that they possess it[1].

Continuous improvement is can be dealt in three conditions[2]

- In 1st condition it motivates one to try despite the fear of mistake. Most of the places the one who makes mistake is considered as "Loser" or "Incapable". This effect one's capability of trying new things & continuous improvement & creates the fear of failing. One must know the cause behind those mistakes so that they can be stopped from reoccurrence.
- 2nd condition motivates & owner everyone who recognize the bottleneck & solve it. This condition is based on the concept that the one who directly involves with the process is the one who made it. As most of the top management personals doesn't have the same knowledge as the worker who is doing that process have.
- The 3rd condition is about asking the people that who to get things improved, it will motivate them towards continuous improvement. It will make improve their decision making skills.

Continuous improvement is a never ending process & it deals in three different tools, i.e. PDCA cycle, standardization & 5W1H

2.1.1 PDCA Cycle

PDCA cycle begins with Shewhart cycle in 1939. Figure 2.3 defines the shewhart cycle relative to precious straight line. Dr. Shewhart wrote in his book that these three steps must go in a circle than in a straight line (as shown in figure). These three steps helps in improving the mass production process as a scientific method. These three process helps in making an assumption, making an experiment & testing the assumption. Three steps provides the basis for acquiring knowledge[2]

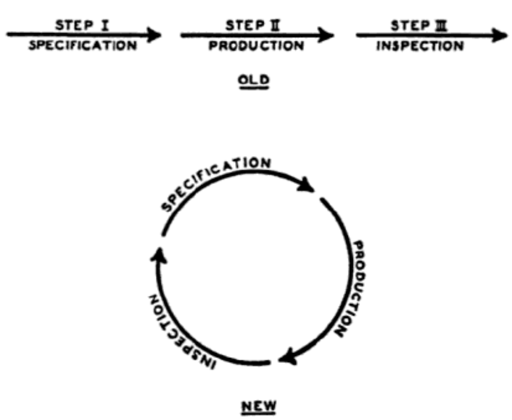


Figure 3Shewhart Cycle, 1939 [3]

In 1950, Dr. Deming put forward his continuous improvement cycle in JUSE, in his continuous improvement cycle Dr. Deming added a fourth step to the cycle & defined the four steps as design, production, sales & research &emphasize the interaction between the four steps & that these steps should be continuously rotating, to achieve the desired quality of product[3].

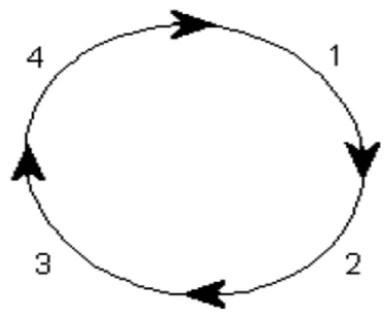


Figure 4 The Deming's Wheel

- Product design
- Test the product
- Bring the product into the market
- Analyze the product through research about the reaction of customer about it
- Re-design the product according to the customer requirement

Deming from 1950 again put forward shewhart cycle in 1986 describing it as

"Any step may need guidance of statistical methodology for economy, speed, and protection from faulty conclusions from failure to test and measure the effects of interactions."

Deming modified the shewhart cycle again & introduced it as shewhart cycle for learning & improvement "PDCA Cycle".

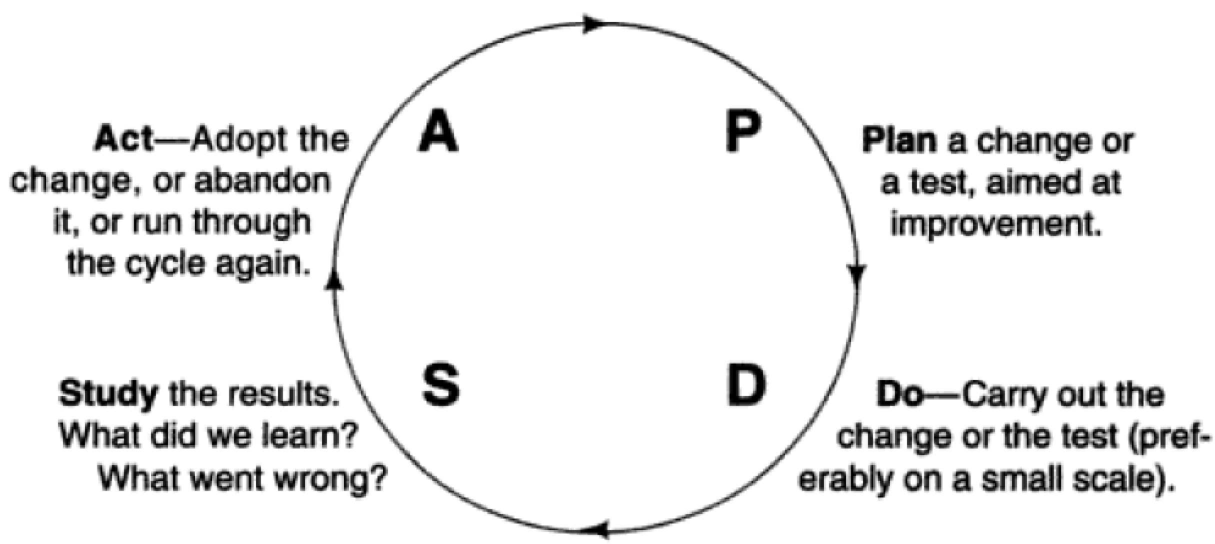


Figure 5 PDSA CYCLE

This cycle in well known as PDCA cycle, but according to Deming everyone must call it as PDSA cycle & not PDCA cycle because PDCA Plan, Do, Check & Act concept of this cycle is in not correct, because he believe that English work "Check" means to hold back[3].

PDSA Cycle is defined in four steps,

- Plan : focus the problem, determine the opportunity & Plan for improvement
- Do : Workout for change
- Study : Analyze the result of change
- Act : If the change result is positive continue it & if not than run the cycle again.

2.1.2 Standardization

It is the process of standardizing all the work & process, if the work & process is standardized it will be easy to teach, improve & documented. All the efforts in the direction of this process is adopted[2].

If the work is kept standardized than there is nothing that can change the resource required for the process. In this manner everyone follows the same operating procedure for work & someone does the process better than existing than that process is made standard. Whenever PDCA cycle is run, it should be the practice to extract the best practice & knowledge, make it a standard. Than this cycle become SDCA (Standard, Do, Check, Act) transformed from PDCA.

2.1.3 5W1H

Rudyard Kipling wrote a poem from which the concept of 5W1H was extracted, that’s why it is also known as Kipling Method.

I keep six honest serving men,

They taught me all I knew,

Their names are what & where & when

& how & why & who.

This poem provided six major management tools based on six questions. These questions provides the basis for collecting the information to act over some plan, identify problem & design solution for it. These can be followed in two ways.

To find the root cause of problem	To find solution for a problem
What is the problem?	What will be done?
Why does it occur?	Why is it being done?
Where is it located?	Where will it be done?
When does it occur?	When will it be done?
Who is involved?	Who will be responsible for it?
How did it appear?	How will it be implemented

2.2 Toyota Production System

As the Ford’s manufacturing facility faced uncontrollable challenge, Taiichi Ohno along with his team come up to face these challenges on shop floor with his team. After few years working with the focus at trail & errors, dealing with each & every problem in order to find the best possible solutions for the MUDA. After detail research they developed a new production system which they called as, the Toyota Production System.

"Muda" is a Japanese word that means "waste". It's a non-value added activity that increase the overheads & doesn't add any value to the product.

TPS was implemented & improved on floor for many years without documenting its theory. Because of this reason it was difficult to train the rest of Toyota's plant & supplier about TPS. To counter this problem Fujio Cho presented TPS house for implementation & training. Now it is known as "Lean House" [4].

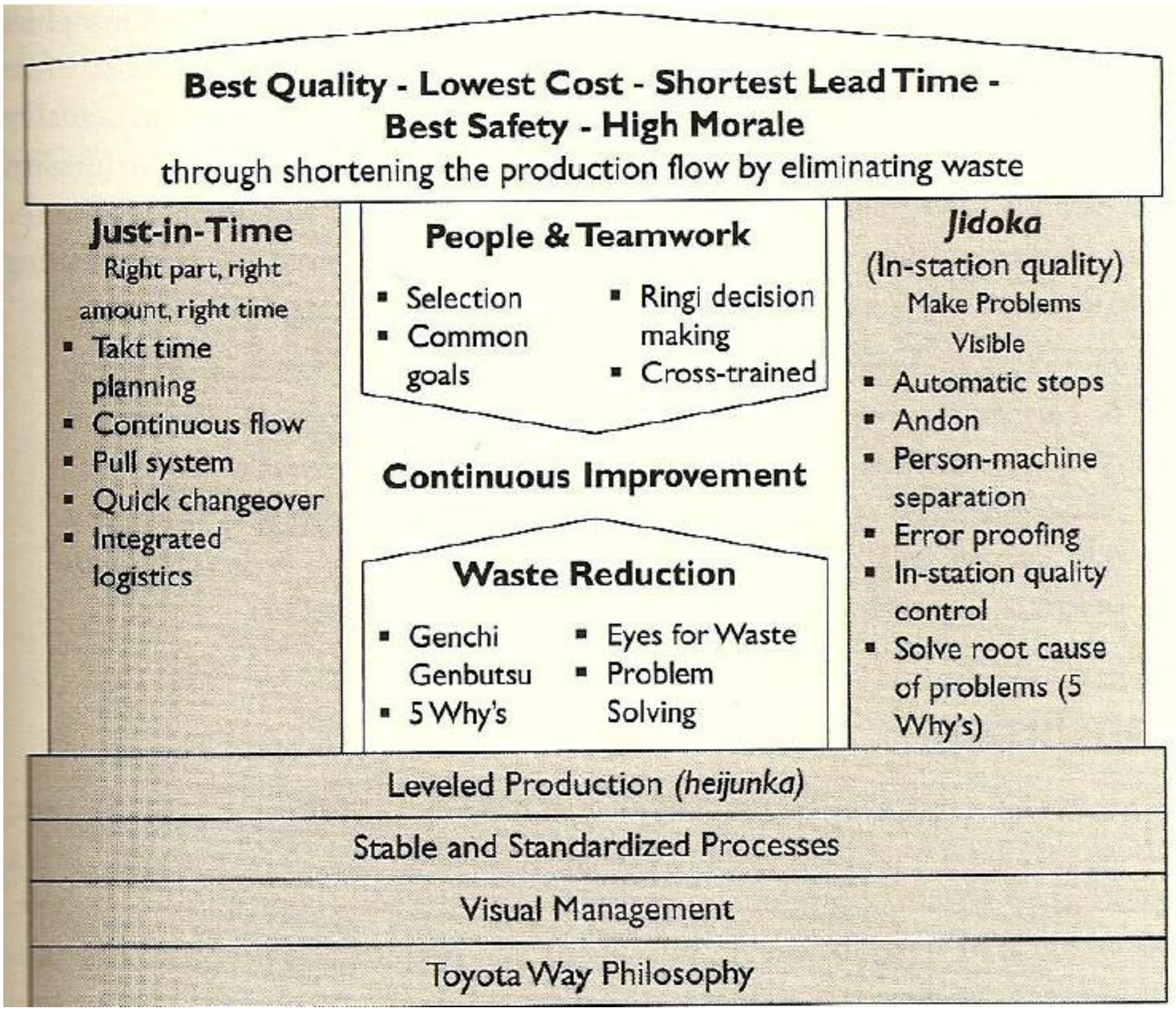


Figure 6 The TPS / Lean House [5]

According to the actual construction of any house, the house can stand strong if its roof, pillar & foundation is strong, that's why lean house focus over best quality, lowest cost, shortest lead time, Just in time, produce what's needed And Jikoda that explains the concept that not a even a single defected piece can enter the next station[4].

2.2.1 Lean Principles

TPS is taken as a concept to increase the value & eliminate the waste. The main lean principles are described below,

- Value

  It is the principle that identify & define that what are the values that customer is willing to pay for.

- Value Stream

  It is the principle that stream line the process activities from raw material to finish goods. Removing the non-value added activities from the system.

- Flow

  It is the principle that explain the flow of process or service with any interruption.

- Pull System

  It is the principle in which the product or service is pulled to the customer opposite the product push system used earlier.

- Perfection

  Add the value to the process & remove all the non-value added activities from the system to achieve the desired perfection.

2.2.2 Lean Tools & Techniques

In this section lean tools & techniques will be explained that are used to achieve the desired lean condition, adding the value to the system & eliminating the non-value added activities. The section will be started with 5s tool's importance & implementation. Taking in to account value stream mapping explaining how to draw it incorporating its main principles. Abc analysis will be also explained that will define which of the company's product is more valuable to the management. At the end of this section benefits & implementation of cellular manufacturing & line balancing will be explained.

2.2.3 5S Technique

It is one of the basic tool of lean production system. Concept behind implementation of 5S is to make efficient, organized & safer work place in order achieve reduction in waste & optimize overall system performance.

This technique got its name from the starting letters of 5 Japanese words i.e. "Seiri", "Seiton", "Seiso", "Seiketsu" & "Shitsuke".

- Seiri (Sort)

  This term defines the concept to collect the items to perform value added activates & separate them from the items that are not useful & cause non value added activities.

- Seiton (Orderliness)

  It provide the concept that everything must be placed on its defined place. Everything place must be predefined & frequent monitoring is required for verification that everything is well placed. Equipment in frequent use must be placed near to workstation & for every equipment an identification mark must be marked at its placement area.

- Seiso (Cleanliness)

    Cleaning the work station frequently reduces the chance of failure & improve the quality of product & performance of the worker.

- Seiktsu (Standardize)

    After implementing the above activities these practices should be performed regularly to get the desire output of this technique of lean production system. So system must be standardized to follow the improvement track.

- Shitsuke (Self Discipline)

    Sustain an improving workplace that is following continuous improvement process.

Most of the organizations mix up 5S with lean production system. They do a lot of workshops about 5s but at the end don't get the desired result of this technique. The concept of 5S must be cleared that it is not a tool to deal with material management & shiny environment, it is a supporting tool for Lean production system to have smooth flow to takt time[4].

2.2.4 Spaghetti Diagram

According to lean production system, before value stream mapping one must follow the process path of the production system defining the internal structure of the process. This activity can be done by moving on the floor following the actual path of the process, draw the layout of actual path & calculate the time & distance travelled for each individual activity, this is called as "Spaghetti Diagram"[4].

2.2.5 Value Stream Mapping

Value is stream mapping is a material & information flow system, value stream mapping was developed by Toyota, in 1999 got the fame through the book of Rother & Shook "Learning to see" [5].

In "Learning to See" Rother & Shook explained value stream mapping as a paper & pencil tool that creates an understanding regarding the product process & information flow in value stream mapping. Value stream mapping must be taken as a production path following customer to supplier, draw every individual activity in involved in material & information flow. Once existing process has been developed in value stream mapping than it can be easily expressed that "how value should flow" [6].

While constructing VSM for any process information flow of that system must be kept at the top part of the VSM whereas material flow of the system is kept in the lower part of the VSM. Both information & material flow in the dimension of left to right. Stock points are adjusted to define the product waiting to be treated in next process with their respective cycle times. It make easier to understand product lead time, process time & value added time.

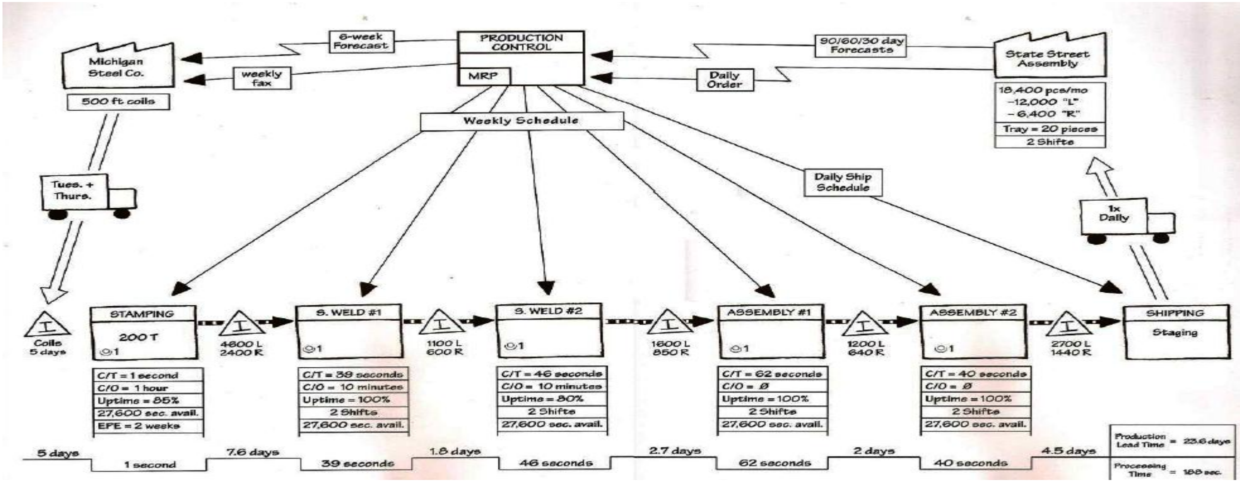


Figure 7 Current State VSM Example [6]

Symbols & icons that are used in the above VSM example represents a language that make VSM easy to understand. Their meanings are explained below:

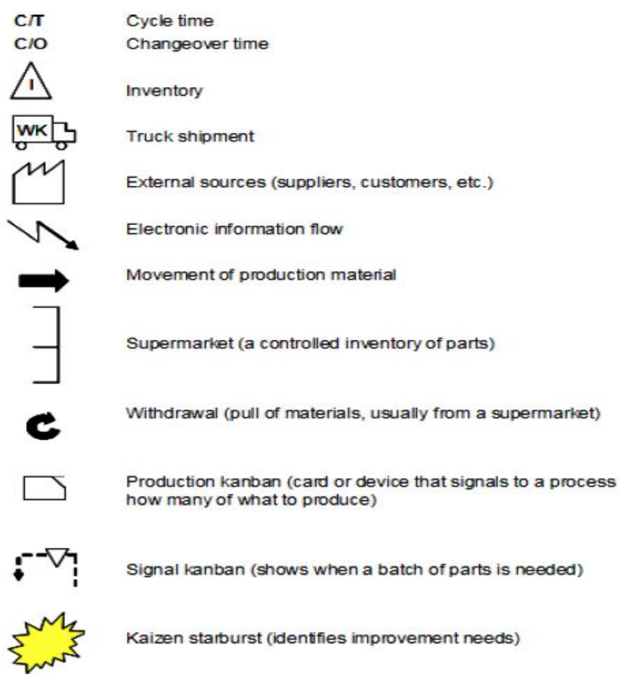


Figure 8 Value Stream Mapping Symbols [7]

In order to develop VSM, product is selected whose mapping is to be done. Current state of material & information flow of selected product is prepared in VSM. After carefully analyzing the current state of VSM, find out the areas increasing the lead time of the process, determine the value added & non value added activities for the process. After completing the analysis over current state of the process, develop improved process plan & develop VSM for that. Below mention figure represents the improved VSM of the previous example[6].

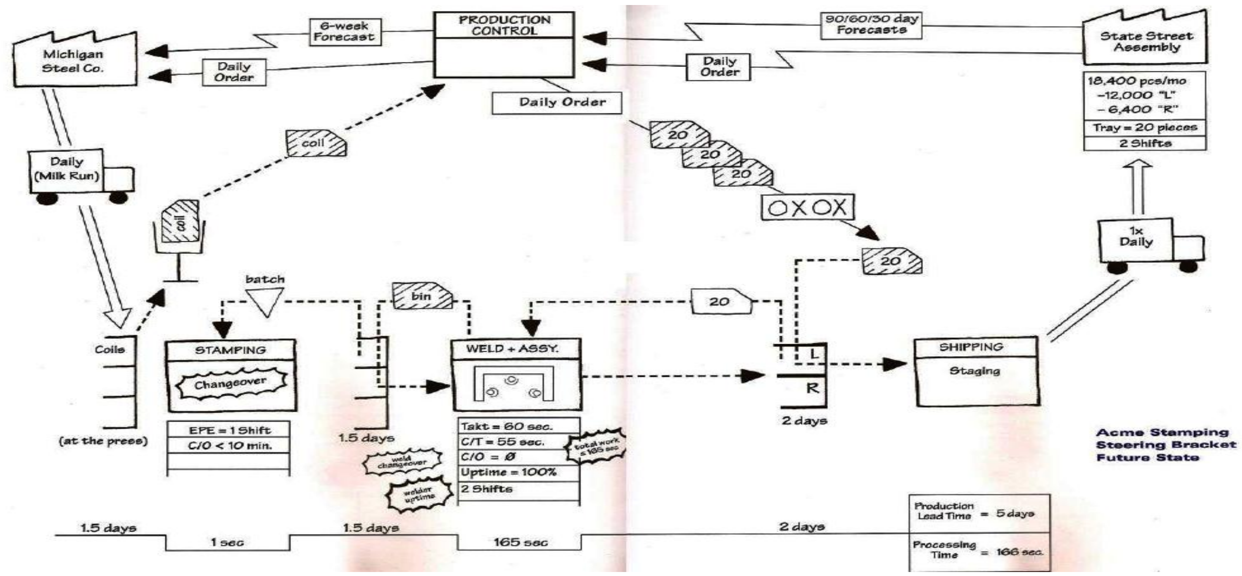


Figure 9 Future State VSM Example [7]

In the future VSM it must be clear that lead time is reduced & improvement take place in process synchronization. There must be a vision of continuous improvement & one must constantly move towards perfection.

2.2.6 ABC Analysis

It is a tool used to set priority so that most important issue can get management attention.

While making ABC analysis product or issues are grouped in order of their estimated importance i.e. A, B & C calculated on pareto chart. It is also known as 80-20 rule, explaining the concept that most of the problems are occurring due to few reoccurring reasons.

For example taking company's annual turnover as a parameter, company's products can be categorized as follows.

- Category A : 20 to 25% products make 60 to 80% turnover
- Category B : 15 to 20% products make 20 to 30% turnover
- Category C : 60 to 65% products make 5 to 10% turnover

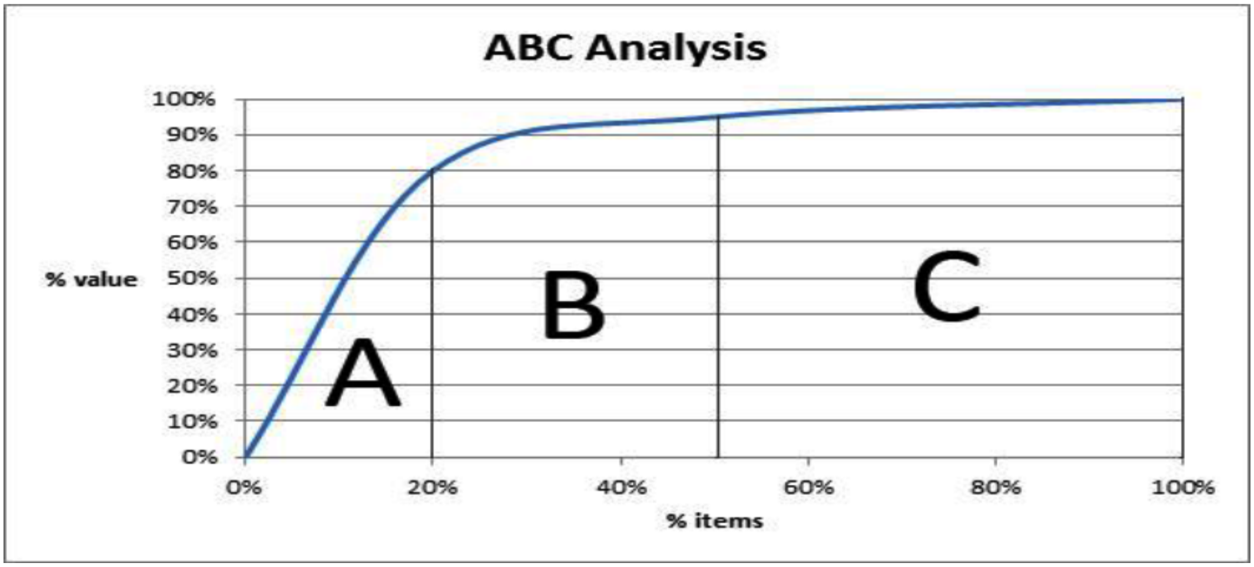


Figure 10 Typical ABC Curve

Percentage for any class is not fixed. It can be made as per priority or any ratio depending upon the importance or requirement.

- Category A

  Products or issues important for the organization depending upon the organization's interest are kept in this class.

- Category B

  Products or issues less important for the organization depending upon the organizations comparatively less interest are kept in this class.

- Category C

  Products or issues which are marginally important for the organization are kept in this class.

2.3 History of Cellular Manufacturing

Cellular manufacturing was proposed by Flanders in 1925 and adopted in Russia by Mitrofanov in 1933 [7]. Burbidge indorsed cellular manufacturing in the 1970s[8]. Initially Japanese used cellular manufacturing in their organizations in 1970s but later cellular manufacturing was adopted in USA 1980s as a tool of JIT (just in time).

2.3.1 Cellular Manufacturing

Now a days every manufacturing facility is facing competition in the shape of shorter product life cycle, fluctuation in demand & worldwide competition to deal with customized product. Therefore the manufacturing facilities are need to be flexible to deal with these conditions. Previously used layouts are not helpful in today's conditions. In these conditions every manufacturing facility is trying to implement some kind of system that can deal with these conditions. Cellular manufacturing system has come with solutions of all the current requirement of the manufacturing system. Cellular manufacturing systems groups the parts in families required identical process of design & manufacturing[9]. Cellular manufacturing system is considered to be the promising alternative manufacturing system[10].

2.3.2 Objective

For implementation of cellular manufacturing system first we need to design cellular manufacturing system. For making cellular system

- Parts with identical operation & design are groups as part families
- Machines are grouped into cells
- Part families are assigned to the respective cells

The main objective of cellular manufacturing is to form cells, part families & assigning part families to respective cells in order reduce material flow cost, throughput time & increase group efficiencies[11]. Different types of methods such as mathematical formulation, heuristics & continuous improvement systems are being used for the purpose of cell formation[12].

While designing layout for cellular manufacturing cell & machine in the cell are placed in such a manner to take maximum output of cell in an efficient manner. The main concept of introducing cellular system is to minimize material handling cost[13].

Layout design in a cell formation process is very important because efficient formation of cell optimize the production system & its performance. Different researcher separate cell formation from layout design[12].

2.3.3 Cell Formation

While formation of cell parts with identical shape & features are grouped as families & these product families are allocated to cells. These cells can be prepared in either way as parts are allocated to the machines or machines are allocated to the part families. Because cellular manufacturing system is very effective in this competitive era, this topic is in much consideration during these decades. Cell is a unit that finds & combines the identical properties of information & product flow. Cell contain resources (man & machine) use to produce identical products. Before cellular manufacturing material movement is so excessive therefore manpower required to complete process is also excessive. Cellular manufacturing enhance the efficiency of material & process flow. Unit deals with cell can be trained to perform multiple operations & made responsible for the efficiency of the relevant cell.U shape layout & less material flow reduce product through put time. Small size of cell reduce the space utilization & hence reduce WIP between stations. Cell takes the advantage of low WIP between stations & that follows the rule of JIT application as Kanban that enhance the workstation utilization[14]

Kanban provides concept marking square areas on production floor between workstation. The rule is applied in production in such a way that if the square areas are complete than stop it & if not fill it.

2.3.4 Virtual Cell

Virtual cell deviate in the sense that complete resources of the system are not brought together. In this type of cell all the resources are dedicated to identical product or process. It helps the production system to have quick throughput using the advantages of cellular system[14].

In 1985 Kone Corp. in Finland published a book in which they extract the concept of creating cell in the assembly of electrical & chemical testing departments. In April 1984 six cells highlights by different colors were created. Different products produced in the cells are identified by the cell colors & worker of the respective cells are responsible for the quality issues[15]

2.3.5 Benefits & Cost

Cellular manufacturing minimize the space utilization by focusing on the process flow in a cell. By formulated cellular manufacturing material flow, throughput time, space utilization. Wip, schedule transaction & rework can be reduced. Further cellular system leads to simplify the increased variability of cost because the cost of producing a product contained within the cell despite of scattered costing process[14]

BAE Systems, Platform Solutions (Fort Wayne, Ind.), manufacturer of aircraft engine monitor & control, formed cells for 80% of their production facility reduces throughput time by 90%, WIP by 70%, space utilization for a product family from 6000 sft. to 1200 sft. with increase in product reliability by 300% & multi skilled the whole unit of the production & nominated as Industry week best plant[16]

It is difficult to separate the advantages of cellular manufacturing in an organization, another exception in this argument is at Steward Inc. manufacturer of nickel, zinc, ferrite parts for electromagnetic interference suppression. According to the case study, formation of cellular manufacturing results in reduction of process time from 14 days to 2 days, WIP by 80%, finished inventory by 60% lateness by 60% & space utilization by 56%. Case study at Hughes Ground Systems Group (Fullerton, Calif.) manufacturer of circuit cards for defense equipment, forms the cell contains 15 workers in 1987. After 1 month they launch the 2nd cell & after few years the whole production of containing about 150 employees was formulated into seven cells. Before implementation throughput time for circuit card from kit to dispatch was 38 weeks but after cellular manufacturing implementation this throughput time was reduced to 30 weeks which was later reduced to 10 weeks [14]

2.4 Line Balancing

In this section, concept of balancing the assembly line & production cell will also be explained. Concept of takt time & cycle time will also be analyzed & relate. Steps for balancing a production or assembly line will also be discussed.

2.4.1 Takt Time

It is defined as the rate at which the each work station's output is required to balance the production cell or assembly line, it is also known as production pace [6]. It synchronized the production facility to produce targeted output from each work station in order to balance the line.

$$\text{Takt Time (s/Unit)} = \frac{\text{Available productive work time per day (s)}}{\text{Customer demand required per day (units)}}$$

Takt time defines the actual production rate at which the workstations are going to be balanced, so therefore there is no need to add any type of allowances for machine down time or any other problem except the planned breaks & preventive maintenance.

2.4.2 Cycle Time

It is the time a finished product take to come out of the production line[17]. It contains all type of delays that occurred while processing a job.

Cycle Time = Processing time + Setup time + waiting time + moving time + inspection & rework time + other delays

Both the times takt time & cycle time should be kept parallel, by calculating approximate time. If it is not done production line cannot be balanced to achieve the predefined target. It can disturb in the following manner

- Increase inventory when cycle time is greater than takt time.
- Use extra resource when cycle time is shorter than cycle time.

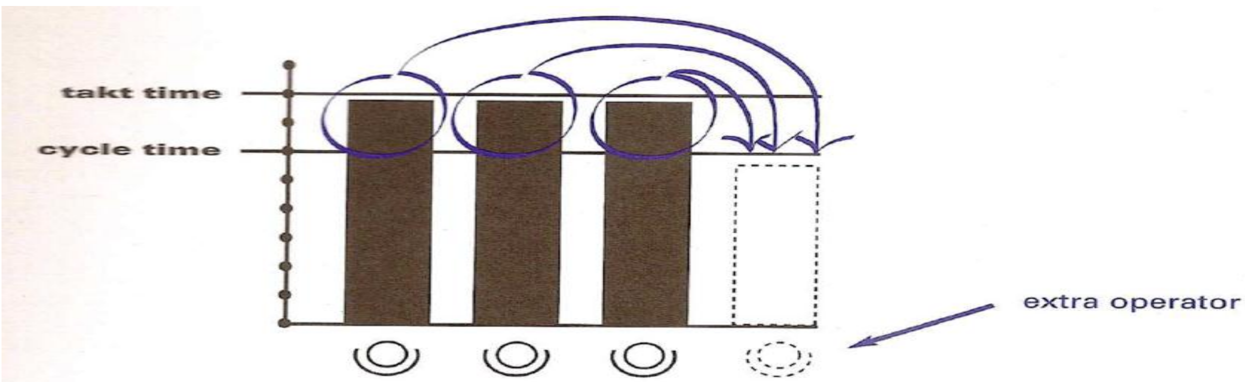


Figure 11 Cycling faster than takt time may require more worker

Comparing takt & cycle times explain that critical condition i.e

- What is the customer's required pace to have one piece out of the line?
- What is the actual pace of the line to produce one piece?

2.4.3 Line balancing Process

Production line can be balanced by incorporating three steps:

- Calculate the takt time for the product to be produced.
- Calculate the number of workstations for the job to be done.
- Assign takt time based operation to each work station.

These steps can be done as explained below.

1. Takt Time

   Takt time can be calculated as dividing the shift time & the target perday.

2. Minimum number of workstations

Minimum number of work stations can be calculate by dividing the total tasks duration time by takt time. Total task duration time can be calculated by adding each individual task time.

$$\text{Number of work stations} = \frac{\text{Sum of task times}}{\text{Takt time}}$$

3. Assign tasks to workstation

Assign the task to each work station such that cycle time & takt time of each individual workstation becomes exactly or approximately equal. Keeping in mind the time & sequence restrictions of the process[17].

After implementing line balancing to the production line its efficiency & max. Production must be calculated. Efficiency & max. Production can be calculated by below mention formula.

$$\text{Max Production} = \frac{\text{Production time per day}}{\text{Bottle neck time}}$$

$$\text{Efficiency} = \frac{\text{Sum of task times}}{\text{Actual number of work stations X Takt time}}$$

2.5 Six Sigma Definition and concept explanation

Six sigma is a tools used to remove the weakness from the system & bridges between the gaps while use for the improvement concept. It uses a structure & statistical tools to identify root cause to understand & minimize the variations in the system. Six sigma is all about conducting the things optimized. It provides an improvement philosophy that uses tools to organize the data in order to solve the problem & originates quick transformational improvements at lower cost. Six sigma project undertakes particular quantitative targets that represents the overall performance of project at each particular step. This philosophy is connected to the theories of Dr. Joseph Juran & Dr. Edwards Deming. Six sigma is a strategy that improve the quality of the system by eliminating imperfections & reasons behind them. Six sigma is a follows customer’s needs & requirement that’s why it’s a customer focus approach [18].

Six sigma demonstrates measurable assembling practices. The advancement of an assembling methodology can be portrayed by a sigma rating showing its yield or the rate of deformity free items it makes. A six sigma procedure is one in which 99.99966% of the items produced are factually desert free (3.4 deformities every million), albeit, as examined underneath, this imperfection level compares to just a 4.5 sigma level. Motorola set an objective of "six sigma" for every last bit of its assembling operations, and this objective turned into an epitome for the administration and building practices used to attain to it.

Six sigma teaches following principles:

- Continuous activities generating steady predictable results are vital in defining organizations success.
- Every business have some operational parameters that can be measured, broke down, controlled & moved forward.
- Achievements are maintained by making everyone following the new developed procedures, this requires special involvement from higher management.

Six sigma is different from all the previous improvements techniques as it can be used to change the organizational culture or it reduce defects & rework by getting involved in operations & undertakes financial results [18].

Another difference is its approach, six sigma takes more clear understanding of process & operations. It uses DMAIC methodology for problem solving. Use as structured problem solving tool is another key difference between six sigma and other tools.

The third difference between six sigma & other quality tools are that it is customer focused. All the six sigma projects are related to customer's requirements & needs, determining these needs using CTQ tool.

Six sigma is a top down approach rather than bottom up, it defines that this approach must be lead, driven & owned by the top management rather than lower level staff [5]. Six sigma despite of other concepts demands top level management to get more involved in the improvement philosophy.

Six sigma plans a different organization including Green Belts, Yellow Belts, and Black Belts etc. Six sigma is making a group for critical thinking with obvious parts & structure for project champions, Black & Green belt is made for critical thinking methodology [6]. Six sigma makes decision on the basis of statistical methods by systematic use of tools & techniques. This decision making tool box consist of many different tools i.e. Control charts, Quality capacity deployment, Design of Experiment, Cause & effect & Lean assembling[18]. It focuses on achieving measureable & quantifiable financial goals.

2.5.1 Six Sigma History

Six sigma has its roots in largest electronic producers Motorola in 1980, where it was started as quality improvement approach. In Motorola it was aimed to improve all the products, goods & services was set by an order of magnitude & established within five years. This concept provided more focus at improvement concept by stressing on production rates. It provided a concept that focuses on real targets not on unreal targets like better or improved only but that the critical consideration is that of becoming sufficiently better expeditiously.

Motorola launched six sigma methodology in 1987 to measure the level of improvements in the process. Motorola focuses at resources while implementation of six sigma that includes human resource, on reducing variations in all manufacturing & administrative processes.

Six sigma has grown a lot from last few decades, success stories of six sigma can be viewed from the organizations who have implemented it successfully[19].

Jack Welch has given six sigma a new height by introducing it as origin of his business in General Electric in 1995. Now six sigma is being used in different sectors as a focused process improvement tool.

Allied Signal, Gillette, Johnson Control, JP Morgan Chase, Johnson & Johnson, Bombardier, Sony, Eastman Kodak, ABB, Caterpillar, American Express, Motorola, General Electric, AlliedSignal (now Honeywell), ABB, Lockheed Martin, Polaroid, Sony, Honda, American Express, Ford, Lear

Corporation and Solectron are the enterprises that have taken six sigma as core improvement factor & have got the maximum benefit out of it.

Six sigma has now moved to every part of the world as it was initially taken into account by US & European countries[18].

Six sigma was derived from the process ability studies i.e. the field of measurement. Six sigma was referred as capacity of all the operations involved in assembling to achieve high extent of yield inside detail. Six sigma quality level defines that 3.4 imperfections can be accepted over per million opportunities (DPMO). Organization that is applying six sigma needs to focus their most important course of action & attempt to control them.

2.5.2 Six Sigma Implementation

According to the survey 50% of the aerospace companies are not satisfied with their six sigma program[20]. Survey on health care sector explains that 54% of the companies are not ready to accept six sigma. After analyzing this ratio the thing that needs to be understood that why do the most of six sigma programs falls flat? Most of the six sigma programs falls flat because we don't have a proper direction to execute this improvement plan[21].

A survey defines that why is this change technique still successful? The basic key factor behind this improvement plan is support of the top management. Without the support of top management it is quite impossible to make this program successful[22]. The new emerged technology has also contributed in its success a lot[22].

- Independent monitoring of large data base
- Statistical tools
- Easy data sharing through internet

Training is the second most important factor contributes in the success of six sigma. Tools used in training of six sigma are used in other quality control methods as well[22]. According to survey tools being taught in industrial training are not being used properly after the training is over[22].But in six sigma these tools are used long after training is over & are much better if retained & practiced.

Six sigma DMAIC concept's successful implementation follows an organized roadmap that keeps overall implementation of the methodology on track[22].

Initially six sigma project requires intense attention of top management with the flexibility of shifting of resources to get the things on the track to get the desired output of the project[22]. But no system can be under consideration for more than few years because after few time it become the working style of the organization. Every organization has a different way of doing it.

Frequent monitoring & resetting of the quality goals & objectives, critical project selection, roadmap to the project team involved, understanding to the critical tools are required, editing of six sigma according to the business requirement & direction training are required in order to keep achieving the desired results [22]. Companies working on six sigma project needs to design a plan that can maintain the system when reaches a maturity[22].

In order to achieve success in the implementation of six sigma & improve its credibility, it needs to produce some quantifiable output, focusing on this immediate achievement focus shifted at scrap & rework reduction because these are easy to handle & considered as good short term goal [22].

The major factor still remains the involvement and support of top management. The previous research in the field of six sigma implementation including the previous research of Antony and Banuelas (2002), Coronado and Antony (2002), Lakhavani (2003), Lynch et al. (2003), Mcadam and Evans (2004), Gijon and Rao (2005), Szeto and Tsang (2005), Ladani et al. (2006), Savolainen and Haikonen (2007), and Davison and Al-Shaghana (2007). Recently, Zu et al. (2008) studied the evolving theory behind the success and implementation of six sigma. While defining Six Sigma programs and uncovering the underlying theory, Schroeder et al. (2008) identified that the principle main impetus is the administration's association in performing numerous Six Sigma capacities, for example, selecting change experts, distinguishing undertaking determination, and encouraging Six Sigma usage [21]

Some important factors that influence implementation & success of six sigma are:

- Involving suppliers in implementation of six sigma.
- Eliminates the difference between six sigma project & other critical projects is important for the successful implementation of six sigma in industrial environment. Six sigma should be penetrated in every department of the organization. It will help in utilizing the employees trained in six sigma can use this methodology in daily working.
- It is important that team or individual who has qualified for the six sigma BB or GB certification must be trained in such a manner that they are not only trained over some particular tools, but they can make the best utilization of the available tools for their organization.
- Execute high-level process mapping and prioritize improvement that is carried out by performing an abnormal state procedure mapping of data stream with the point of distinguishing and organizing change opportunities. This methodical methodology ought to be equipped for comprehension the current stream of data and its related quality creation with it. The primary point ought to be to lessen variety (inefficient) exercises all through the whole process being referred to incorporating obsolete data in the frameworks database, repetitive methodology, copy and befuddling paper work, long setup times for the procedure, botches in place passage, botches in system exchange and SAP [21].

2.5.3 Tools and methodologies used by six sigma during DMAIC Project

The major tool and software's used during the course of the project will be explained and applied as DMAIC steps progress they will be briefly stated in this section for quick reference.

Pareto Charts & Control Charts

- SIPOC (Suppliers, Inputs, Process, Outputs, Customers)
- VOC-CTQ (critical to quality) & Stakeholder Analysis
- Communication Plan (5W1H) & Initial & Final Skill Matrix
- Process Capability & Cause & Effect Diagram: Fishbone
- Implementation Plan (5W2H) & SWOT Analysis

The major software used is Mini Tab which is a statically data analysis tool tailored to handle and facilitate six sigma, lean and other quality improvements methodologies. Its major usage is in graphical analysis and hypothesis testing.

3. RESEARCH METHODOLOGY

3.1.1 Six Sigma "A Tool for Process Improvement"

Six sigma focuses at controlling the process variations causing defects in final product. To minimize the process variations it uses process optimization tools & training as a preventive measures. Process variation effects the overall productivity of the industry & hence effects the customer as well. So implementation of six sigma tools identifies the causes behind the process variation & support to improve the overall process to achieve predefined targets.

Six sigma focuses on the below mentioned points to improve process variations:

- A continuous effort to reduce variation in process outputs is key to business success
- Manufacturing and business processes can be measured, analyzed, improved and controlled
- In order to achieve best quality improvement results role of upper management is very critical

Six sigma follows the concept that if process variation occurs than it is essential to analyze the process & take action accordingly. Improved process will improve the overall output of the system. This step will help in gaining customer's confidence & trust. It will also help in improving system's efficiency & productivity & also increase the financial saving. For the successful implementation of six sigma all the must staff must be having the training regarding six sigma tools & techniques. Six sigma implementation can make the process so capable that it can product within the specification. Process that achieves the six sigma level is able to produce the product with minimum defects as 3.4 defects per million opportunities.

Six sigma focuses at improving the overall manufacturing process & takes quality as a function of process capability to produce item within specification.

Six sigma mainly uses two main methodologies one is called Define, measure, analyze, improve and control, usually known as **DMAIC** and other is define, measure, analyze, design and verify, known as **DMADV**. Both the methodologies are based on Edwards Deming's, Plan-Do-Check-Act cycle. **DMADV** is used for creating new processes to improve the overall productivity.

Other methodologies that are being used during six sigma implementation are given as:

DCCDI (Define, Customer, Concept, Design and Implement)

- CDOC (Conceptualize, Design, Optimize and Control)
- DCDOV (Define, Concept, Design, Optimize and Verify)
- DMADOV (Define, Measure, Analyze, Design, Optimize and Verify)
- DMEDI (Define, Measure, Explore, Develop and Implement)
- IDOV (Identify, Design, Optimize and validate)
- IIDOV (Invent, Innovate, Develop, Optimize and validate)

3.1.2 Six Sigma Implementation Process

Six sigma project while implementation based on two major steps:

- Identify Losses

  Identify priorities & assign projects to achieve business objective

  Identify Losses

- Analyze & Eliminate Losses

  Analyze & solve problems (DMAIC Project)

  Analyze & reduce changeover time

Six sigma is a latest concept with respect to TQM (Total quality management). Initially six sigma was never considered as substitute for TQM. Six sigma & TQM have many properties & in common & both can be implemented in either business environment. Where implementation of TQM improved the quality standards of the business, six sigma has the ability to produce more précised results.

TQM is related with developing, implementing & maintaining standards according to the business process requirement. It focuses on continuing the current quality standards & drafting new quality improvement standards for achieving the desired quality level. It develops the culture that everyone seeks for improving the quality of a system to the desired level.

Six sigma is a continuous process improvement tool, it's a process improvement concept that focus to improve quality to such standard that it can produce defects as less as 3.4 defects per million. Statistical process control (SPC) monitors & control the business process. SPC & TQM focuses on only quality improvement & at certain point quality improvement cannot be further derived. Whereas six sigma is a concept that takes quality improvement to more high level.

Difference between six sigma & TQM is that they both have different approach. Six sigma tries to improve the quality of system by reducing the number of defects whereas TQM improves the quality to fulfill internal system requirement. The conclusion for both might be same.

Six sigma differ from previous cost saving concepts that saves the operational cost of system & reduce the quality on the other hand as six sigma focus to reduce the operational cost of the system by reducing the defects, cycle time & cost saving in the system. It eliminates non value added activities from the system & optimize the system by improving value added activities.

TQM concept improve some targeted operations within the process, whereas six sigma focus on improving all the operation included in the process. Six sigma develop professionals after a certified training as "Six Sigma Black belt" whereas TQM is taken as part time activity that a non-manager can deal with.

3.1.3 Factors Involving In Successful Implementation of Six Sigma

For the successful implementation of six sigma it must be followed as top to bottom approach. It needs full commitment & support of top management for successful implementation. Top management must be involved in developing & managing the system's parameters. They must take keen interest & participation in improvement projects. Implementing & following six sigma tools & techniques should be the part of everyone's job. Lack of top management's attention towards six sigma implementation will minimize its actual impact & effectiveness.

Six sigma is a breakthrough management strategy, because it involves adjustments to the firm's values and culture for its introduction. It brings considerable change in organization's structure. People in the organization are scared of the change occur in the organization, the resist the change & they are unaware of why the change is required. It mostly happen in the organizations where mistakes are treated as blunders therefore the workers find the easy way out by hiding defects. Whereas six sigma is concerned, six sigma supports the open & comfortable culture where defects are considered as opportunities.

Organizations implementing six sigma have proper criteria for selecting the project. Top management of the organization selects the project by keeping in mind all factors effecting on it. In this manner only top management can select & proceed six sigma project. Whereas other quality improvement concepts follows bottom up approach where on floor workers are the main part of the project.

Six sigma produced process improvement specialist by training them to the level of Black belt. All type of business organizations use these specialist to improve their process. These specialists are trained with all tools & techniques for process improvement for 4 weeks. Many organizations also train most, if not all, employees assigned to projects in six sigma basics. Six sigma also produced instructor who provide technical assistance to the organization, they are above black belt level & they are known as master black belt. Every organization when plan an improvement project forms a team collecting employees having best knowledge of the system & green belt training. Member from top management is selected to be the team leader who report to top management about the progress & achievement of project & team.Six sigma uses a structured method for process improvement called DMAIC (define, measure, analyze, improve, and control) method.

3.2 DMAIC (Define, Measure, Analyze, Improve, Control)

Considering the scope of the project the focus of research will be on productivity optimization of the closing line. DMAIC methodology will be taken as a best tool to analyze & understand the data & improvement process using different DMAIC tools. Process & productivity optimization can be done by implementing Six Sigma methodology. DMAIC can be used in any business considering the needs of the system. Key steps involved in DMAIC is given in the figure below.

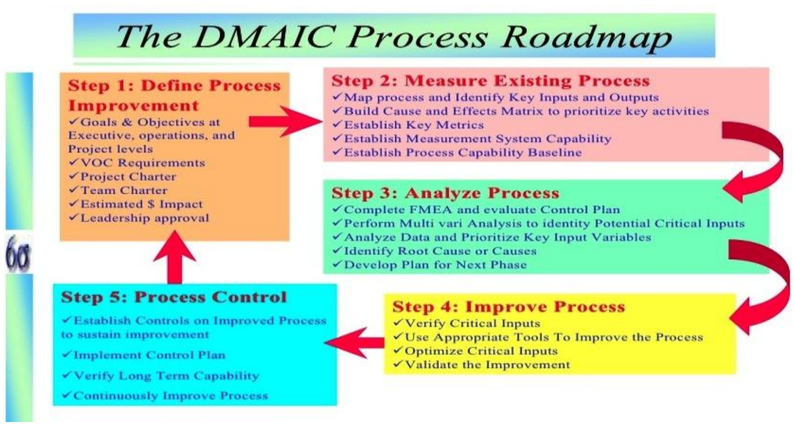


Figure 12 The DMAIC Process Road Map

3.2.1 Define Phase

Objective: This phase defines the problem & scope. Detail of problem includes the impact felt by the customer or process & the duration it has been existing in the system. There are different tools which are used in this phase like SIPOC, Voice of Customer (CTQ Tree (Critical to Quality), Stakeholder Analysis, Quality Function deployment and developing a Communication Plan.

Output:

- A clear description of the expected improvement & its measurement parameters.
- High level process map will be defined.
- Customer's needs & expectations will be listed.

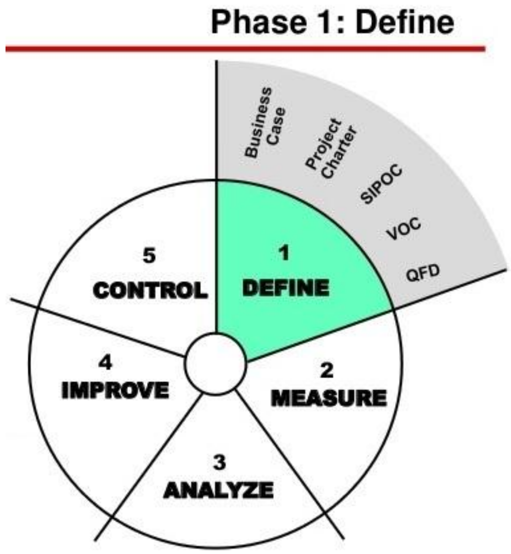


Figure 13 Define Phase

3.2.2 Measure Phase

Objective: Estimates the improvement efforts by gathering information regarding the current situation of the system. There are different tools used for this purpose i.e. Process mapping, Data collection plan, Measurement system analysis, System capability analysis.

Output:

- Data that provide more focused area of problem occurrence.
- Data that defines current sigma level.
- A more focused problem statement.

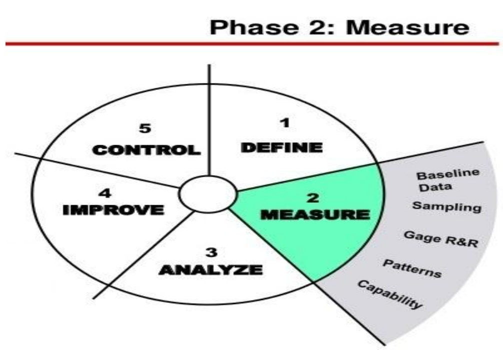


Figure 14 Measure Phase

3.2.3 Analyze Phase

Objective: Identify deep root cause & confirm them with data available. There are different methods used for this phase are Regression Analysis, Design of Experiment and Process analysis.

Output:

- It provides the theory that has been tested & confirmed.

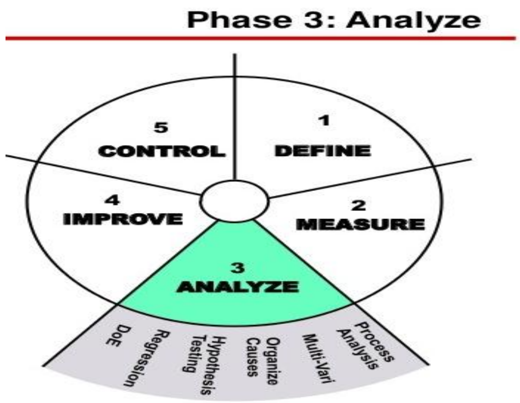


Figure 15 Analyze Phase

3.2.4 Improve Phase

Objective: Prepare solution for the problem in the process by implementing different tools like Poka yoke, DOE, FMEA.

Output:

- Identification of planned, tested actions that should eliminate or reduce the impact of identified root cause.

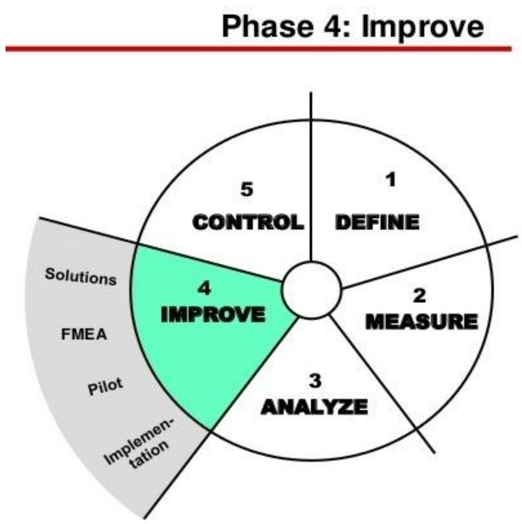


Figure 16 Improve Phase

3.2.5 Control Phase

Objective: Using data, evolution of solution of problems and future plan and also maintain the standing operating procedure.

Output:

- Analysis of data before and after Improvement

- Well monitored system
- Completed documentation of process results

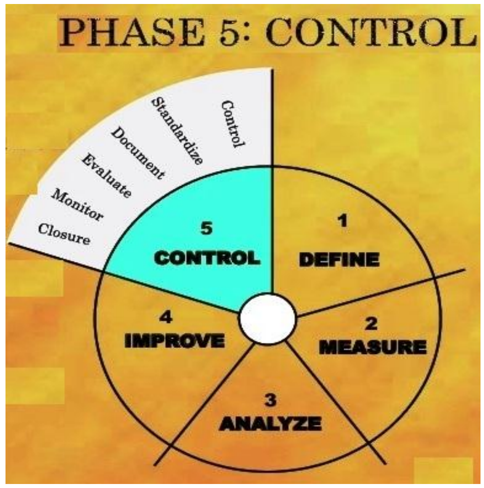


Figure 17 Control Phase

4. DATA & ANALYSIS

4.1 Introduction

In this data & analysis section, project team by using the DMAIC methodology will define the concept of the project, than relevant data to the project will be gathered & analyzed to find the bottle neck in the process & key potential areas for the improvement in the project. On the basis of analysis, improvement plan will be made & executed. Finally the parameters will be set to control & maintain the improved structure of the overall process.

4.2 DEFINE PHASE:

Define phase of the project helps to identify the problem according to the demand of customers. In this phase of Project Problems and future roadmap for the project are defined.
The project started with the investigation of the problem. This was evaluated in greater depth with the help of different tools which is used in define phase like SIPOC, Voice of Customer, Stakeholder Analysis, Thought Map and Communication Plan.

4.2.1 Thought Process Map:

For the successful implementation of DMAIC it must start with concrete foundation, Thought process map is a tool that make a concrete foundation for a thought process map. Thought process visually reflects entire project team's thought questions & ideas to accomplish the project goals. It should be the prime tool to start the DMAIC process for improvement of any process. It's alive structure that changes throughout the project & has no set format. Thought map uses DMAIC tool that should be implemented. It is a tool for ensuring all potential questions & issues of a project have been identified & addressed from the beginning of project to completion.

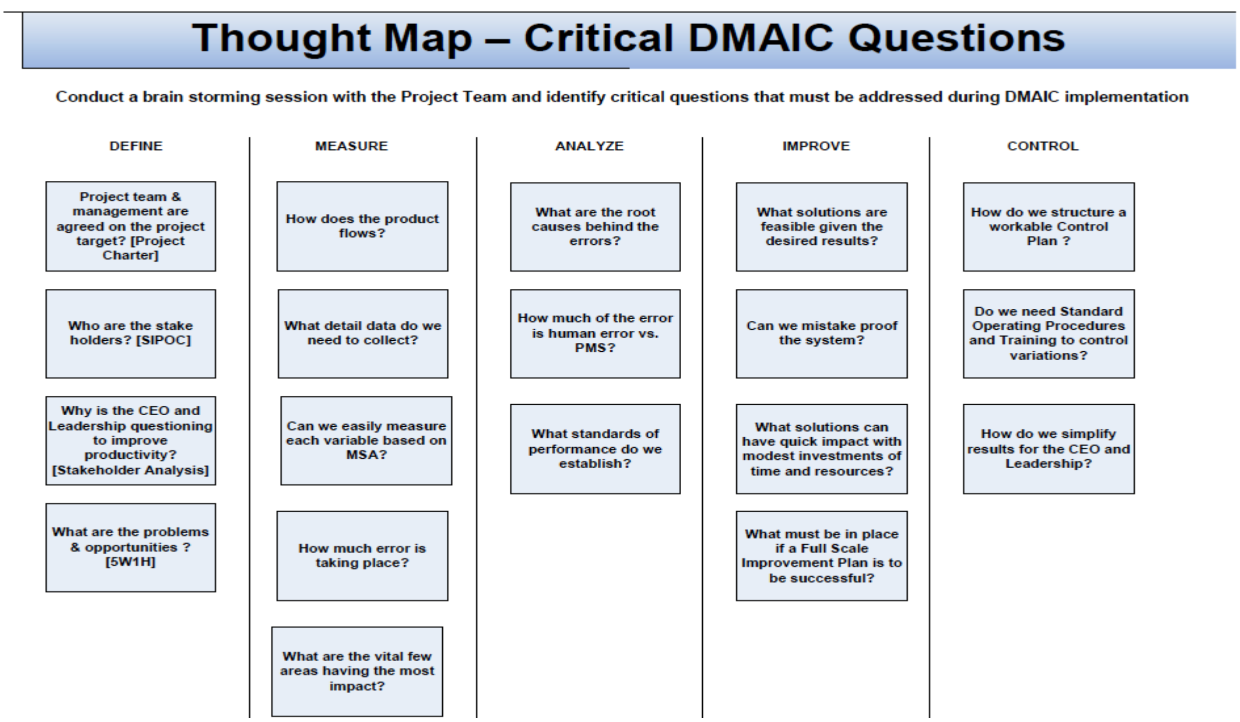


Figure 18 Thought Map

4.2.2 Project Charter

A project Charter is established by manufacturing facility. Production and industrial engineering Departments helped in understanding current performance of facility. Area effecting overall capacity of organization is Closing Lines. The low productivity of closing lines causing monitory & efficiency losses. As a business case it is defined that Project Focus would be on optimizing closing line's productivity & improving efficiency using available resources. Below mention table explains the contents of Project Charter in details.

Project Title: Enhancing Process Capability Using DMAIC Approach in Shoe Manufacturing Industry	
Project Leader: Muhammad Amir Habib	**Team Members:**
Business Case (Importance):	**Department** / **Designation**
Shoe manufacturing industry has some bottle necks in its process that decreses its productivity. Root cause analysis & removing bottle necks using DMAIC would help to increase process capacility & reduce that manufactuing cost of the product.	Production – Asst.Manager Industrial Engg. – Asst.Manager
Problem Statement (Purpose)	**Goal Statement:**
Shoe manufacturing industry is facing problem regarding low productivity in Closing (Sewing) section. Manufacturing cost per pair is meansured very high due low utilization of resources	Increase productivity by 10-15% Reduce manufacturing cost per pair
Project Scope:	**Deliverables:**
A single closing line will be in scope of project that is facing maximum problem with productivity, all the perspective of the line will be studied & monitored.	Root cause analysis of low productivity Developing SOPs for optimization Implement & control SOPs
Resources:	**Stakeholders:**
IED team members Production Department team members	Head of Industrial Engg. Department Factory Manager General Manager

Figure 19 Project Charter

4.2.3 SIPOC Diagram

SIPOC (Supplier, input, process, output, and customer) is a tool used to express the complete process flow from start till end. It is also considered as high level process map because it only contains precise detail about the process. SIPOC provide basis to project team to easily understand the process & find the area of improvement. It is used in Define phase of DMAIC methodology.

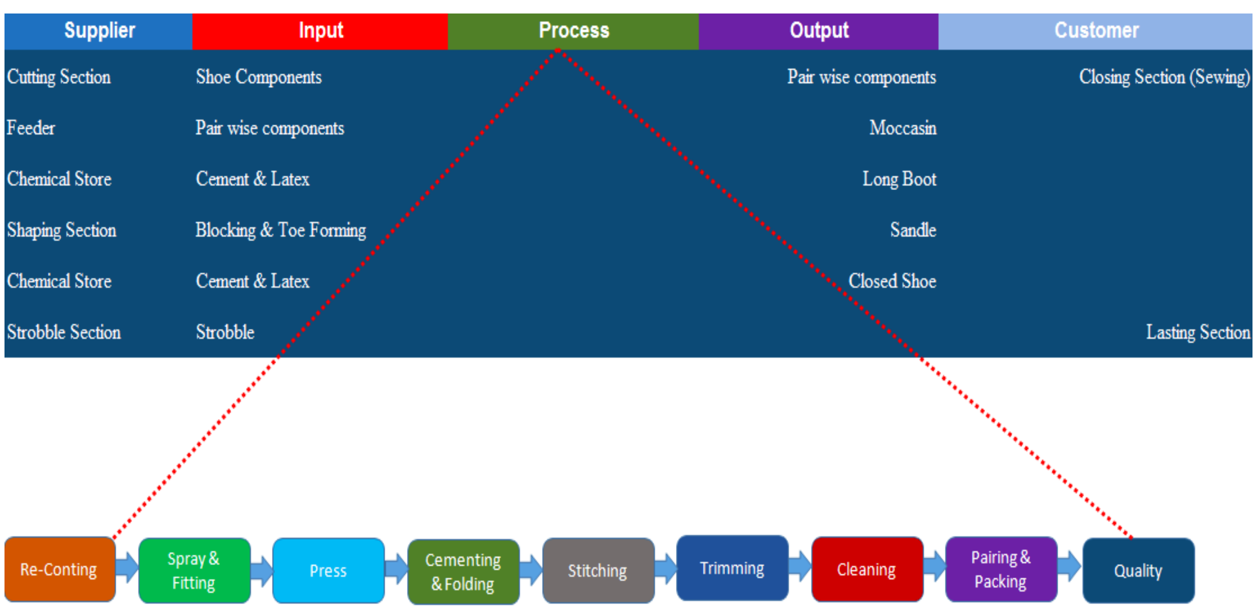


Figure 20 SIPOC Diagram

Project team started to prepare SIPOC process map from center column “Process”. Process column provide complete detail of the flow & each step of the process provide detail about some action being done.

After filling the detail regarding process & developing understanding on that project team than move to find out the output of each individual action of process & customer related to that action. After completing this process, output & customer section the project team worked reverse on finding out the inputs & suppliers for that action of process.

SIPOC helps in enhancing the vision to understand the process activities and their connections. It leads to understand the potential areas for improvement & develop an understanding that how to deal that problem.

4.2.4 Voice of Customer (VOC)

Voice of customer is customer’s requirement, preferences & expectation regarding the project under consideration. VOC defines the customer according to its demands & expectation. It provide the basis to focus & target the areas where the projected customers have their interest. It provides strong basis to implement DMAIC methodology for improvement.

Now the project team after detail analysis & observation have prepared a VOC chart highlighting the major demands of the customer from DMAIC implementation project.

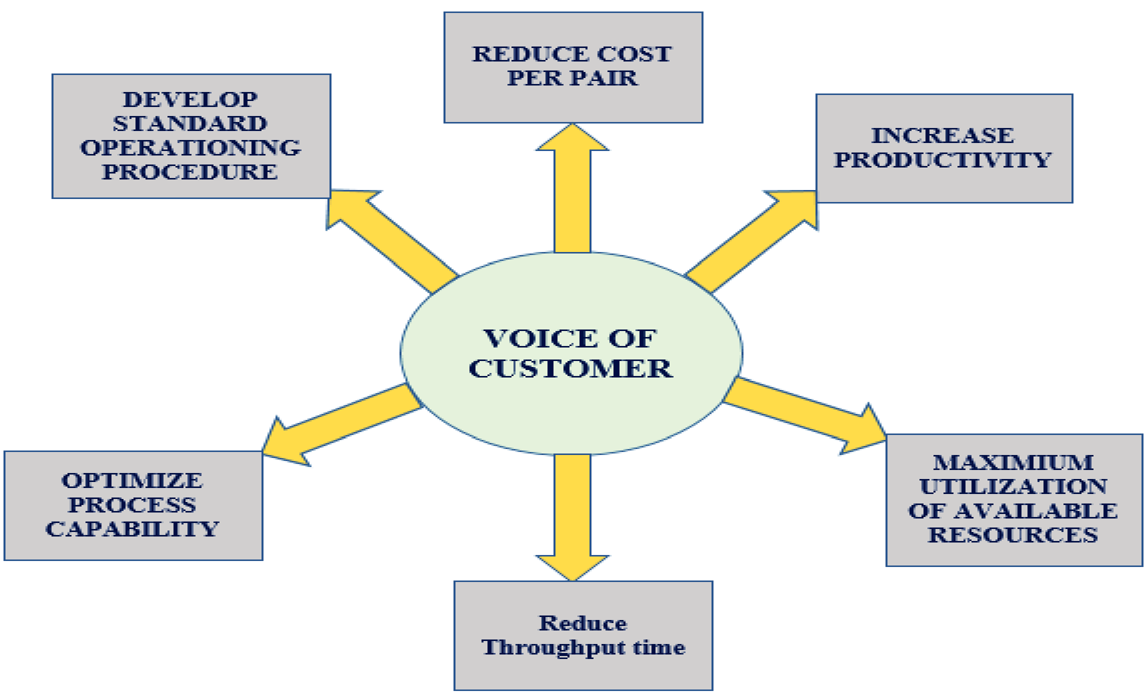


Figure 21 VOC Diagram

Now from above VOC diagram it is quite clear that customers are focusing on increasing productivity using available resources of the system & reducing the cost per pair for the production by reducing the changeover time & developing the structure for line balancing to maximize the profitability of the organization. For all that customer is demanding the project team to develop standard operational data, because on the basis of that customer can identify the actual targets of the closing lines.

4.2.5 Communication Plan

The communication plan in define phase of DMAIC methodology is inducted to channelize the communication system between every individual who is the part of the project. Project team will be going to 5W1h tool for developing a communication plan. It is a tool that by the virtue of its methodology take the project in a much systematic way as it focuses on exploring the problem occurred & opportunity available.

In this closing line's productivity optimization project using 5W1H project team will be focusing on each & every aspect involve in effecting the productivity of the closing line.

What	Why	How	Where	Who	When
Explaning project statement to all concern personals (Stake holders)	To be agreed on concerns	Conduct a meeting	Factory meeting room	Team leader/ Team members	22-Dec-14
Explaning project statement to Line's foreman & workers	To provide awareness to everyone about project task	Conduct a meeting	At production floor	Team leader/ Team members	23-Dec-14
Daily meeting with line	To define the line's current day's target & previous day's efficiency	Conduct a meeting	At production floor	Foreman / Project team member	Daily
Weekly meeting	To discuss project status & issues	Conduct a meeting	Factory meeting room	Team leader/ Team members	On every Monday
Phase Completion meeting	To discuss the findings & achievements of the respective phase	Conduct a meeting	Factory meeting room	Team leader/ Team members	At the end of every phase

Figure 22 5 Why Communication Plan

4.2.6 Define Phase Outcome

After implementing different tools in define phase project team has found that all the stake holders are concerned about the closing lines' underutilization because it having major impact on the overall organization's efficiency & productivity & they believe that there is enough space of improvement. According to stake holders' if the closing lines' performance can be improved it will be beneficial for the organization in different ways.

- Reduce throughput time
- Reduce cost per pair
- Improve productivity
- Improve resource utilization
- Reduce factory overheads
- Non value added operations can be removed

Now keeping in mind the stake holders' requirements, project team will be working in that direction to achieve them.

4.3 Measure Phase

Measure is that phase of DMAIC process in which the process under observation will be properly elaborated 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. It intakes creating operational definitions for each characteristic of the process, gathering base line data for capability studies and performing studies for the measurement procedure conformance. The basic outcomes of Measure phase provide us information about the process capability, a process map and the definition of the measurement system to be used.

Measure phase will provide us the bases for:

- Understand key measures and data types to be used
- Establish quality of measurement systems and data
- Determine baseline measures for the process
- Define process capability and entitlement
- Provide detailed understanding of the current process and identify the steps for project focus

4.3.1 Steps To Be Followed in Measure Phase

We will be following the steps for our process understanding data collection &evaluation.

Process Maps Operational Def. Measurement Data Overview Focused Problem

Data Collection System Analysis Trend StatementPlan Capability

4.3.2 Understand Process

4.3.2.1 Activity Based Process Mapping

Process mapping is done to visually document the process at an actionable level of detail. It aids understanding of three possible views, 1- What we think it is? 2-What it actually is? 3- What it should be? It will help us in having better understanding of the input to the process to help build a Y=f(x) view of the process. This converts the focus of the problem under consideration on the process on which it's taking place. It focuses on identifying bottlenecks, value added & value added steps, duplications, measurement points, redundancies & rework loops. It guides the way to identify the opportunities for improvement.

By using activity based process mapping for two different products MOCCASIN &LONG BOOTS we will be able to understand the process for both the products precisely & will be able to understand that what the main difference is between these two products? What are non-value added activities which can be adjusted or removed from the process? &how this process should work?

Now we have to prepare detailed process map for both the products.

4.3.2.2 MOCCASIN PROCESS MAPPING

Figure 23 Moccasin Process Flow Chart

4.3.2.3 LONG BOOTS PROCESS MAPPING:

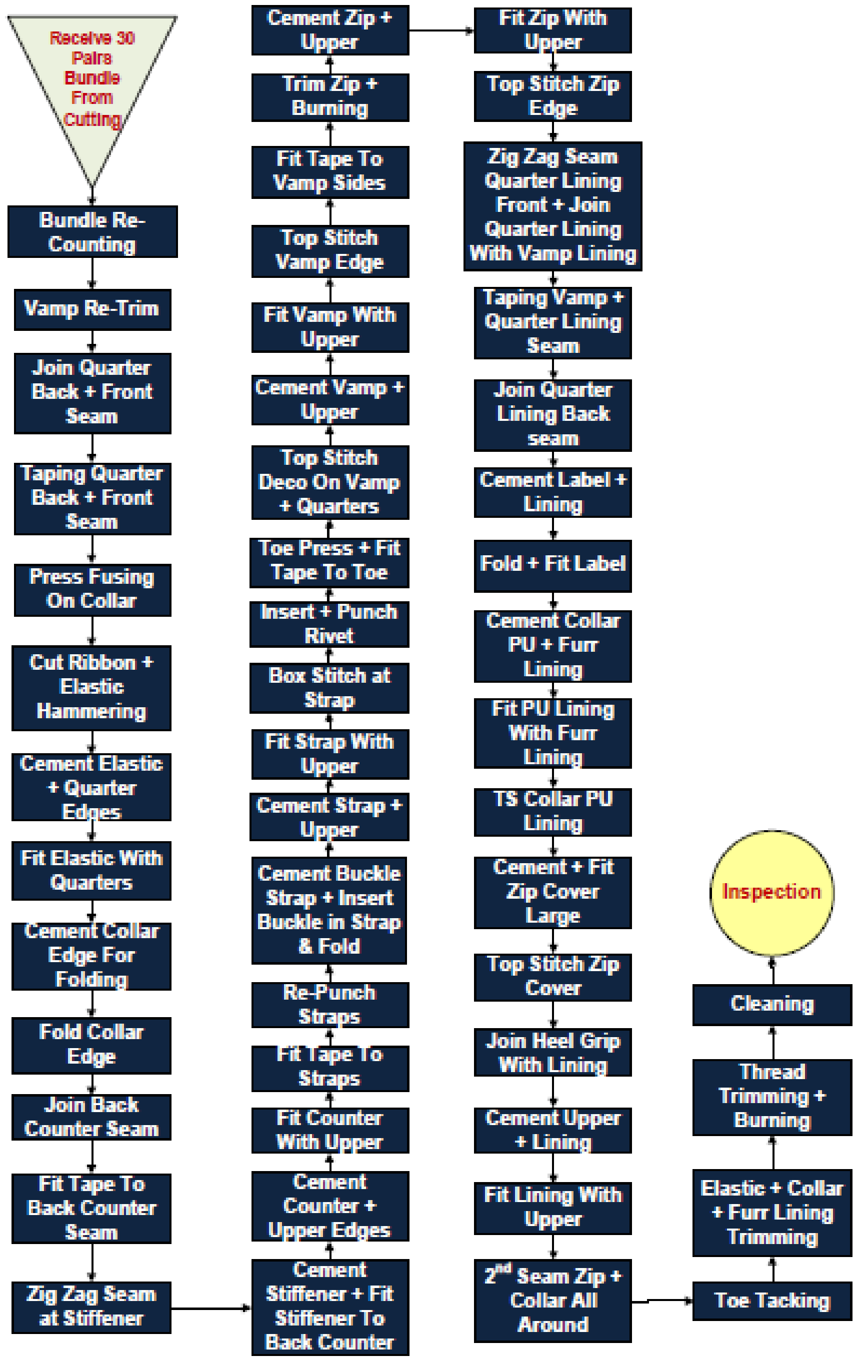


Figure 24 Long Boot Process Flow Chart

4.3.3 Collect Data

The only way to collect the right data success is to do it systematically. Because of this, a data collection plan is the first step in the data collection process.

The focus should on collecting that which will help in elaborating the problem, as well as uncovering any factors that provide clues about how, when, where, or in what circumstances the problem occurs or worsened. During formulation, the team should analyze what data to collect&also ensure that the collection process is valid. Systematically data collection & analysis will lead us to the root cause of the major problem. It will help us in analyzing the rate at which process is working & what's the process capability.

After having understanding about the problem in above phase, the team will start collecting data to measure the projects outputs in more detail & in different angles. Now we will befollowingthe below stated data collection plan.

DATA COLLECTION PLAN						
WHO	WHAT			WHEN	WHY	HOW
Responsible	Operational Definition	Data Type	Sample Size or Frequency	Time	Question to be Answered	Recording Method
Project Team	Compiling operational data bank	Time in Seconds	10 Readings	Day Shift	Standard Allowed Minute for Operation	Time Study
Project Team	Prepare OBD	Closing Operations	10 Articles	Day Shift	Total SAM for article	Process breakdown
Project Team	Calculation of Targets	No. of Pairs	10 Articles	Day Shift	Efficiency of Line	SAM based
Project Team	Calculate Efficiency	Percentage of Efficiency	5 Analysis	Day Shift	Line Losses	Target vs Actual output
Project Team	Calculate Lost Pairs	No. of Pairs	5 Analysis	Day Shift	Calculate Monitory Loss	Target vs Actual output

Figure 25 Data Collection Plan

Now according to the above formulated data collection plan, the project team needs to prepare complete comprehensive operational data bank for the shoe making process (in CLOSING section). Because the industry doesn't have any standardized operational data bank at which closing line's performance could be measured? Operational data bank will be containing each and every single operation's SAM (Standard Allowed Minute) for closing line.

4.3.4 Measurement System Analysis

4.3.4.1 FORMULATION OF DATA BANK

Operational data bank will contain all the operations performed during the manufacturing of shoe (in closing line). Operational data bank will contain detail formulation for calculation of SAM for operations. We will be following below mention steps for formulation of SAM (Standard Allowed Minutes).

1. Operation name.
2. Operation type (Manual or Machine)
3. Take 7 reading of each operation using stop watch (Single Cycle Time).
4. Calculate the average for the 7 readings (Avg. Single Cycle Time).
5. Convert that ASC into minute value.
6. Provide the Rating Factor (RF) for that operation on the basis of Speed, Feed & Handling of operator.
7. Multiply minute value with rating factor to calculate Basic Minute Value (BMV).

$$BMV = ASC * RF$$

8. SAM (Standard Allowed Minute) will be calculated using below mention formula.

4.3.4.2 SAM CALCULATION:

SAM = BMV + PF% of BMV + MA% of BMV

4.3.4.3 CLOSING (Sewing) Section SAM Data Bank

Closing SAM Data Bank														
Sr	Operation	M/C	Readings							ASC	Min	RF	BMV	SAM
			1	2	3	4	5	6	7					
1	Allign Backer	Man	8	10	7	6	6	8	7	7	0.12	90%	0.11	0.123
2	Cement Bk Counter Edge	Man	8	8	7	9	8	7	8	8	0.13	95%	0.12	0.137
3	Cement Upper Edge To Fit Backer	Man	9	11	9	13	11	10	9	10	0.17	90%	0.15	0.170
4	Fit Bk Counter	Man	20	19	21	20	19	21	21	20	0.34	90%	0.30	0.332
5	Cement Lining Full (Long Boot)	Man	33	37	35	43	41	36	39	38	0.63	90%	0.57	0.622
6	Cement Upper Full (Long Boot)	Man	42	36	33	39	37	41	34	37	0.62	85%	0.53	0.583
7	Fit Lining Full (Long Boot)	Man	96	94	91	95	94	91	95	94	1.56	95%	1.48	1.632
8	Cement Lining Full (Mid Boot)	Man	39	31	37	34	39	29	31	34	0.57	95%	0.54	0.597
9	Cement Upper Full (Mid Boot)	Man	33	29	32	36	30	34	29	32	0.53	95%	0.50	0.555
10	Fit Lining (Mid Boot)	Man	80	87	77	89	85	81	83	83	1.39	95%	1.32	1.448
11	Cement Upper To Fit Zip (Mid Boot)	Man	24	20	23	21	21	21	24	22	0.37	85%	0.31	0.343
12	Cement Zip (Mid Boot)	Man	8	10	12	9	8	8	10	9	0.15	100%	0.15	0.170
13	Fit Zip (Mid Boot)	Man	29	25	27	25	23	27	24	26	0.43	85%	0.36	0.401
14	Cement Vamp	Man	12	14	14	13	14	15	12	13	0.22	90%	0.20	0.222
15	Cement Upper For Vamp Fit	Man	10	12	9	10	9	9	8	10	0.16	95%	0.15	0.167
16	Fit Vamp With Upper	Man	24	21	23	19	22	21	22	22	0.36	115%	0.42	0.458
17	Cleaning Zip (Mid Boot)	Man	13	10	12	14	11	13	12	12	0.20	90%	0.18	0.200
18	Cleaning Elastic (Mid Boot)	Man	9	9	10	12	11	9	11	10	0.17	90%	0.15	0.167
19	TS Zip All Around (Mid Boot)	M/C	47	42	50	51	46	49	43	47	0.78	95%	0.74	0.896
20	TS Zip Edge (Mid Boot)	M/C	32	36	39	35	34	35	32	35	0.58	80%	0.46	0.559
21	Cement Tongue Foam	Man	10	9	9	8	7	8	8	8	0.14	95%	0.13	0.147
22	Fit Tongue Foam	Man	14	17	12	14	14	12	15	14	0.23	85%	0.20	0.218
23	Tape Quarter Front & Bk Seam	M/C	7	6	6	6	7	9	6	7	0.11	100%	0.11	0.135
24	Convyer Press	M/C	5	5	5	5	5	5	5	5	0.08	100%	0.08	0.101
25	Rotary Press	M/C	19	18	22	24	21	23	19	21	0.35	90%	0.31	0.378
26	Insert Buckle Loop	Man	8	5	8	6	6	5	7	6	0.11	100%	0.11	0.118
27	Insert Buckle	Man	5	5	7	6	5	7	7	6	0.10	100%	0.10	0.110
28	Cement Collar Foam	Man	5	6	5	5	5	6	6	5	0.09	100%	0.09	0.100
29	Fit Collar Foam	Man	9	11	13	10	11	9	9	10	0.17	100%	0.17	0.189
30	Eyelet Punch	Man	3	3	4	2	3	3	3	3	0.05	100%	0.05	0.055
31	Insert Rivet (Mnl)	Man	10	9	8	9	9	8	10	9	0.15	90%	0.14	0.149
32	Punch Rivet (Mnl)	Man	2	3	2	2	3	2	2	2	0.04	90%	0.03	0.038
33	Self Collar Folding	Man	22	19	21	23	19	18	21	20	0.34	90%	0.31	0.337
34	Cement Collar PU Lining	Man	9	7	8	9	10	9	9	9	0.15	95%	0.14	0.152
35	Cement Lining Collar	Man	13	11	12	14	11	12	12	12	0.20	90%	0.18	0.200
36	Fit Collar PU Lining	Man	17	14	14	16	13	19	17	16	0.26	90%	0.24	0.259
37	Top Stitch Collar Lining	M/C	11	15	16	14	11	16	15	14	0.23	95%	0.22	0.268
38	Bk Seam Hammering	M/C	6	5	5	6	6	6	5	6	0.09	95%	0.09	0.107
39	Poly Bag Handeling	Man	6	6	5	6	9	7	5	6	0.10	90%	0.09	0.104
40	Cement Quarter Bk Seam Strap	Man	9	9	8	9	11	8	9	9	0.15	90%	0.14	0.149

41	Fit Quarter Bk Seam Strap	Man	22	29	27	25	19	26	27	25	0.42	80%	0.33	0.367
42	Top Stitch V Patch Mid Boot	M/C	23	27	25	27	21	23	24	24	0.40	90%	0.36	0.440
43	Blocking	M/C	9	7	11	9	9	9	9	9	0.15	95%	0.14	0.172
44	Cement Wool Lining To Fit With Collar	Man	17	21	19	17	17	19	17	18	0.30	85%	0.26	0.283
45	Fit Wool Lining With Collar	Man	24	21	19	22	24	21	23	22	0.37	90%	0.33	0.363
46	Fit Toe Press	Man	16	15	17	17	15	16	15	16	0.26	90%	0.24	0.262
47	Zig Zag Stiffener	M/C	7	5	5	7	7	5	6	6	0.10	100%	0.10	0.121
48	Cement T Shape Bk Counter Deco Patch	Man	19	21	17	21	19	18	20	19	0.32	80%	0.26	0.283
49	Fold & Fit T Shape Deco Patch	Man	26	21	23	27	22	24	22	24	0.39	90%	0.35	0.389
50	Temporary Lacing (16 Holes)	Man	42	38	39	36	41	38	44	40	0.66	85%	0.56	0.619
51	Cement Heel Grip	Man	8	8	9	8	8	7	8	8	0.13	90%	0.12	0.132
52	Cement Lining For Heel Grip	Man	12	15	13	11	12	11	14	13	0.21	85%	0.18	0.196
53	Fit Heel Grip	Man	9	11	8	7	8	9	9	9	0.15	90%	0.13	0.144
54	TS Heel Grip	M/C	12	15	14	17	13	12	12	14	0.23	95%	0.21	0.259
55	Cement Strap For Lining Fit	Man	7	5	5	6	7	6	5	6	0.10	95%	0.09	0.102
56	Cement Strap Lining	Man	10	9	9	12	8	9	8	9	0.15	90%	0.14	0.153
57	Fit Strap With Lining	Man	5	7	8	5	5	7	6	6	0.10	95%	0.10	0.107
58	Cement Strap Edge For Fitting	Man	4	5	5	4	4	5	4	4	0.07	100%	0.07	0.081
59	Cement Upper For Strap Fit	Man	8	9	7	7	8	8	7	8	0.13	90%	0.12	0.127
60	Fit Strap On Upper	Man	6	5	6	6	6	5	5	6	0.09	95%	0.09	0.097
61	Edge Stitch Arrow Strap	M/C	16	19	17	19	16	18	18	18	0.29	90%	0.26	0.318
62	Edge Stitch Square Strap	M/C	18	18	16	19	22	17	18	18	0.30	90%	0.27	0.331
63	Edge Stitch Round Strap	M/C	15	19	17	19	16	18	17	17	0.29	90%	0.26	0.313
64	Re- Punch Strap	Man	2	2	2	2	2	2	2	2	0.03	100%	0.03	0.037
65	Cement Lining (Vamp+Heel Grip)	Man	18	19	19	17	16	18	19	18	0.30	85%	0.26	0.281
66	Cement Upper (Vamp+Heel Grip)	Man	19	16	17	19	16	17	16	17	0.29	80%	0.23	0.251
67	Fit Lining (Vamp+Heel Grip)	Man	61	65	67	59	57	53	61	60	1.01	85%	0.86	0.942
68	Cement Zip Cover (Mid Boot)	Man	8	8	11	12	7	9	10	9	0.15	85%	0.13	0.145
69	Cement Lining To Fit Zip Cover (Mid Boot)	Man	11	9	12	11	9	8	9	10	0.16	85%	0.14	0.154
70	Fit Zip Cover (Mid Boot)	Man	9	10	11	9	9	9	10	10	0.16	90%	0.14	0.158
71	Cement Zip Cover to Fit With Lining (Long Boot)	Man	13	10	14	11	14	11	12	12	0.20	95%	0.19	0.211
72	Cement Lining to Fit With Zip Cover (Long Boot)	Man	11	12	15	14	15	12	12	13	0.22	95%	0.21	0.226
73	Fit Zip Cover (Long Boot)	Man	12	10	13	15	12	10	12	12	0.20	95%	0.19	0.209
74	TS Zip All Around (Long Boot)	M/C	63	61	67	64	69	64	63	64	1.07	85%	0.91	1.102
75	TS Zip Cover (Mid Boot)	M/C	17	14	16	17	16	15	13	15	0.26	95%	0.24	0.295
76	TS Zip Cover (Long Boot)	M/C	22	19	18	19	17	19	18	19	0.31	90%	0.28	0.342
77	TS Zip Edge (Long Boot)	M/C	42	47	49	46	45	42	41	45	0.74	90%	0.67	0.807
78	Join Quarter Lining Pc ZZ (Mid Boot)	M/C	11	8	9	11	9	10	10	10	0.16	90%	0.15	0.176
79	Quarter Lining Bk Seam (Long Boot)	M/C	28	33	29	31	36	31	29	31	0.52	90%	0.47	0.561
80	Quarter Bk Seam (Long Boot)	M/C	28	29	31	27	28	29	27	28	0.47	90%	0.43	0.515
81	Quarter Bk Seam (Mid Boot)	M/C	14	11	12	15	14	15	13	13	0.22	90%	0.20	0.243
82	Box Stitch With Cross	M/C	42	44	46	49	41	47	44	45	0.75	90%	0.67	0.810
83	U Stitch	M/C	31	27	27	34	32	31	34	31	0.51	85%	0.44	0.528
84	TS Deco Bk Counter	M/C	15	13	20	17	19	16	15	16	0.27	90%	0.25	0.298
85	TS Deco Vamp	M/C	18	22	19	21	18	18	21	20	0.33	90%	0.29	0.354
86	Edge Stitch Vamp	M/C	21	26	27	25	23	25	21	24	0.40	90%	0.36	0.435
87	Edge Stitch Bk Counter	M/C	13	15	15	12	13	13	15	14	0.23	90%	0.21	0.248
88	Elastic Lining Trim (Long Boot)	Man	9	9	9	10	8	9	9	9	0.15	85%	0.13	0.140

89	Zip Lining Trim (Long Boot)	Man	57	50	54	51	52	57	52	53	0.89	90%	0.80	0.879
90	Zip Lining Trim (Mid Boot)	Man	25	31	24	29	24	23	24	26	0.43	90%	0.39	0.424
91	Zip Patch Lining Trim (Mid Boot)	Man	16	19	18	16	23	18	21	19	0.31	90%	0.28	0.309
92	Cement Elastic For Ribbon Fitting (Boot)	Man	3	3	4	3	3	4	3	3	0.05	100%	0.05	0.060
93	Fit Ribbon & Cut	Man	6	6	6	5	6	7	6	6	0.10	95%	0.10	0.105
94	Vamp Reinforcement Stitch	M/C	19	21	17	19	22	19	21	20	0.33	90%	0.30	0.357
95	Cement Eyelet Pcs	Man	9	11	8	12	11	9	9	10	0.16	95%	0.16	0.172
96	Fit Eyelet Pcs	Man	12	10	14	12	11	12	11	12	0.20	95%	0.19	0.204
97	Vamp ReTrim	M/C	9	7	9	8	8	9	8	8	0.14	95%	0.13	0.158
98	Tack buckle loop	M/C	9	6	8	6	7	7	7	7	0.12	95%	0.11	0.137
99	Trim Zip	Man	5	3	4	3	3	3	3	3	0.06	100%	0.06	0.063
100	Mark Elastic	Man	2	3	2	3	3	3	3	3	0.05	100%	0.05	0.050
101	Cut Elastic	Man	4	5	5	4	4	4	4	4	0.07	100%	0.07	0.079
102	Pairing & packing	Man	8	9	8	8	8	9	9	8	0.14	95%	0.13	0.147
103	Trim Bottom	M/C	12	14	12	16	12	12	12	13	0.21	95%	0.20	0.246
104	Cement Tongue Edge For Fitting	Man	8	9	11	9	8	8	7	9	0.14	95%	0.14	0.149
105	Cement Vamp Edge For Tongue Fitting	Man	13	9	12	12	11	13	11	12	0.19	85%	0.16	0.180
106	Fit Tongue To Vamp	Man	10	9	9	9	9	9	10	9	0.15	90%	0.14	0.153
107	Top Stitch Tongue Vamp Seam	M/C	9	7	9	7	7	7	9	8	0.13	95%	0.12	0.150
108	Pleat Making	Man	39	44	41	44	43	44	45	43	0.71	80%	0.57	0.629
109	Thread Triming	Man	13	15	15	19	15	16	12	15	0.25	95%	0.24	0.261
110	Thread Burning	Man	15	11	17	15	16	15	14	15	0.25	95%	0.23	0.256
111	Zip Burning	Man	6	7	5	4	5	5	5	5	0.09	95%	0.08	0.092

Figure 26 Closing (Sewing) SAM Data Bank

Comprehensive data bank for closing section has been completed containing SAM for every single operation being performed in closing lines.

Now we will be able to prepare operational breakdown **(OBD)**.

4.3.5 Data Overview

4.3.5.1 PREPARATION OF OPERATIONAL BREAK DOWN (OBD)

Project team will be preparing operational breakdown for five Moccasin articles & 5 Long boots articles. The main purpose of preparing OBD is to calculate the total allowed minute to produce one pair so that its final target can be calculated for complete shift on the given manpower.

OBD will be containing sequential operational flow, SAM per component, frequency of the operation, SAM per pair, Target per hour for the particular operation at 80%&Theoretical man level required for that operation.

Total SAM calculated at the end of OBD will be the sum of all individual operation's SAM per pair, after concluding the total SAM of an article we will be calculating the target per shift of an article based on the **Shift Time = 480 Minutes & Manpower = 45 worker**

4.3.5.2 FORMULA FOR CALCULATION OF TARGET

$$\text{TARGET} = \frac{\text{Shift Time X Manpower}}{\text{SAM}}$$

4.3.6 Operational Breakdown for Long Boots

4.3.6.1 ARTICLE#LB-1 (LONG BOOT)

FOOTWEAR	SEWING (CLOSING) OPERATION BREAK DOWN	DATE
	LONG BOOT	

ARTICLE#:(UPDATED)	LB#1	CUSTOMER:	Caprice
CONSTRUCTION:	LASTED	LINE# / SECTION	L-1

SR#	Code	OPERATION	Description	M/C	SAM	FREQ	SAM PER PAIR	TGT PER HOUR	TH. MAN LVL	
1	CS44	Cement for backer fitting(spot)		Man	0.10	12	1.20	35	0.8	
2	OT6	Allign Backer (1 Component)		MAN	0.16	12	1.92	22	1.3	
3	PR1	Rotary Press 1 Cycle		PRESS	0.51	2	1.02	41	0.7	
4	TR101	Vamp Re-Trim		TRIM	0.22	2	0.44	95	0.3	
5	TP12	Fit Tape To Toe		MAN	0.16	2	0.33	128	0.2	
6	TP17	Toe Puff		PRESS	0.28	2	0.56	75	0.4	
7	PF5	Fit Fusing On Collar (Single Pc) Boots		Press	0.27	4	1.08	39	0.7	
8	JQ102	Join Qrter Frnt/ Bk Seam (Medium)	BK SEAM	SNL	0.33	2	0.66	64	0.4	
9	TP8	Taping Quarter Front/ Bk Seam		TAPE	0.15	2	0.30	140	0.2	
10	SP4	Spray (Any small Component)	DECO PC & FOAM	MAN	0.11	4	0.44	95	0.3	
11	FW1	Whole Fitting (Small)	FOAM FIT DECO PC	Man	0.25	2	0.50	84	0.3	
12	SP4	Spray (Any small Component)	BACKER	MAN	0.11	2	0.22	191	0.1	
13	FB1	Fit backer	ON FOAM	Man	0.15	2	0.30	140	0.2	
14	ST10	Top Stitch Deco Straight On Booty Collar With Foam	TS DECO ON DECO PC	SNL	0.11	22	2.42	17	1.6	
15	CE1	Edge Cementing (Small)	F QTRS SIDE PC	Man	0.17	4	0.68	62	0.5	
16	FE1	Edge Fitting (Small)	F QTRS SIDE PC	Man	0.22	2	0.44	95	0.3	
17	ST4	Top Stitch Straight	F QTRS SIDE PC	SNL	0.18	2	0.36	117	0.2	
18	CE2	Edge Cementing (Medium)	QTRS OUT SDIE	Man	0.22	4	0.88	48	0.6	
19	FE2	Edge Fitting (Medium)	QTRS OUT SDIE	Man	0.36	2	0.72	58	0.5	
20	ST8	Top Stitch Straight 1	QTRS OUT SDIE	SNL	0.25	2	0.50	84	0.3	
21	SD103	Top Stitch Deco On Quarters		SNL	0.20	2	0.40	105	0.3	
22	HE1	Elastic Hmmaering		M/C	0.09	2	0.18	233	0.1	
23	CE101	Cement Elastic (Small)		Man	0.14	2	0.28	150	0.2	
24	CE1	Edge Cementing (Small)	QTRS	Man	0.17	2	0.34	124	0.2	
25	FE5	Fit Elastic Edge	WITH QTR	Man	0.17	2	0.34	124	0.2	
26	CC102	Cement Collar Edge For Folding		Man	0.31	2	0.62	68	0.4	
27	FC102	Fold Collar Edge		Man	0.46	2	0.92	46	0.6	
28	CC101	Cement Counter Edge for fitting		Man	0.15	2	0.30	140	0.2	
29	CU108	Cement Uppr For Bk Counter Fitting		Man	0.22	2	0.44	95	0.3	
30	FC101	Fit Back Counter To Upper (Boots)		Man	0.38	2	0.76	55	0.5	
31	SC101	Ts Back Counter Edge		SNL	0.33	2	0.66	64	0.4	
32	SD101	Top Stitch Deco Back Counter		SNL	0.28	2	0.56	75	0.4	
33	CV101	Cement Vamp Edge for fitting		Man	0.22	2	0.44	95	0.3	
34	CU101	Cement Upper Edge For Vamp Fit		Man	0.22	2	0.44	95	0.3	
35	FV101	Fit Vamp To Upper (Boots)		Man	0.61	2	1.22	34	0.8	
36	SV101	Ts Vamp Edge(Booty)		SNL	0.59	2	1.18	36	0.8	
37	SD102	Top Stitch Deco Vamp		SNL	0.44	2	0.88	48	0.6	
38	TP5	Fit tape to vamp sides		Man	0.24	2	0.49	86	0.3	
39	CE1	Edge Cementing (Small)	VAMP SIDE	Man	0.17	2	0.34	124	0.2	
40	FE1	Edge Fitting (Small)	VAMP SIDE	Man	0.22	2	0.44	95	0.3	
41	PF6	Press Fusing	ON STRAP	Press	0.28	4	1.12	38	0.8	
42	SP4	Spray (Any small Component)	SIDE STRAP& LINING	MAN	0.11	4	0.44	95	0.3	
43	FS16	Fit Side strap (Small)		Man	0.13	2	0.26	162	0.2	
44	SS27	Top stitch Side strap XS		SNL	0.27	2	0.54	78	0.4	
45	OT7	Mark Strap Elastic		MAN	0.08	2	0.16	263	0.1	
46	OT8	Cut Strap Elastic		MAN	0.06	2	0.12	350	0.1	
47	CE5	Cement Elastic Strap Edges		Man	0.11	2	0.22	191	0.1	
48	FB101	Insert Buckle In Strap + Fold	& LOOP	Man	0.25	2	0.50	84	0.3	
49	CS21	Cement Back Strap Edges		Man	0.11	2	0.22	191	0.1	
50	CE5	Cement Elastic Strap Edges		Man	0.11	2	0.22	191	0.1	
51	FE5	Fit Elastic Edge	WITH BACK STRAP	Man	0.17	2	0.34	124	0.2	
52	SP4	Spray (Any small Component)	BK STRAP & LINING	MAN	0.11	4	0.44	95	0.3	
53	FS12	Fit Back strap (small)		Man	0.19	2	0.38	111	0.3	
54	SB1	Box Stitch	BACK STRAP	SNL	0.28	2	0.56	75	0.4	
55	CU104	Cement Straps To Fit With Upper		Man	0.11	4	0.44	95	0.3	
56	CU105	Cement Upper For Strap Fitting		Man	0.11	4	0.44	95	0.3	
57	FS103	Fit Strap With Upper		Man	0.17	4	0.68	62	0.5	
58	CE1	Edge Cementing (Small)	FOR ZIP FOLD	Man	0.17	2	0.34	124	0.2	
59	OT105	Fold Zip		MAn	0.16	2	0.32	131	0.2	
60	CZ102	Cement Zip (Medium)		Man	0.25	2	0.50	84	0.3	
61	CU103	Cement Upper Fr Zip Fit (Medium)		Man	0.30	2	0.60	70	0.4	
62	FZ102	Fit Zip (Medium)		Man	0.54	2	1.08	39	0.7	
63	TR102	Trim Zip		MAN	0.07	2	0.14	300	0.1	
64	SZ102	Top Stitch Zip Edge (Medium)		SNL	0.57	2	1.14	37	0.8	
65	ZQ103	Zig Zag Quarter Lining Front Seam(M)		ZZ	0.33	2	0.66	64	0.4	
66	JQ107	Join Qtr Lining Bk Seam (Small)		SNL	0.20	2	0.40	105	0.3	
67	JQ106	Join Qrter Lining With Vamp Lining		ZZ	0.28	2	0.56	75	0.4	
68	TP14	Taping Vamp Zig Zag Seam		MAN	0.24	2	0.47	89	0.3	
69	HV1	Hammering Vamp ZZ seam		M/C	0.24	2	0.48	88	0.3	
70	ZL1	Zig Zag Lining Lock		ZZ	0.20	2	0.40	105	0.3	

71	OT67	Cut		MAn	0.10	3	**0.30**	140	0.2	
72	CL106	Cement Label		Man	0.09	3	**0.27**	156	0.2	
73	CL103	Cement Collr Pu Lining		Man	0.20	2	**0.40**	105	0.3	
74	FL103	Fold & Fit Label		Man	0.13	3	**0.39**	108	0.3	
75	CL103	Cement Collr Pu Lining		Man	0.20	2	**0.40**	105	0.3	
76	CL104	Cement Fur Lining		Man	0.19	2	**0.38**	111	0.3	
77	FL101	Fit Pu Lining With Fur Lining		Man	0.22	2	**0.44**	95	0.3	
78	SC102	Ts Collar Pu Lining		SNL	0.26	2	**0.52**	81	0.4	
79	CZ2	Cement Zip Cover Medium		Man	0.17	2	**0.34**	124	0.2	
80	FZ103	Fit Zip Cover With Fur Lining Medium		Man	0.18	2	**0.36**	117	0.2	
81	SZ104	Ts Zip Cover Piece (Mid)		SNL	0.28	2	**0.56**	75	0.4	
82	CH101	Cement Heel Grip		Man	0.15	2	**0.30**	140	0.2	
83	CL105	Cement Lining For Heel Grip Fitting		Man	0.20	2	**0.40**	105	0.3	
84	FH101	Fit Heel Grip With Lining		Man	0.22	2	**0.44**	95	0.3	
85	SH101	Ts Heel Grip		SNL	0.25	2	**0.50**	84	0.3	
86	SL4	Set Lining With Collar		SNL	0.40	2	**0.80**	53	0.5	
87	CE2	Edge Cementing (Medium)	COLLAR	Man	0.22	2	**0.44**	95	0.3	
88	FE10	Fold Edge Medium		Man	0.30	2	**0.60**	70	0.4	
89	TL2	Turning lining Edge		Man	0.28	2	**0.56**	75	0.4	
90	CU107	Cement Upper (Full) Medium		Man	0.59	2	**1.18**	36	0.8	
91	CL102	Cement Lining (Full) Medium		Man	0.65	2	**1.30**	32	0.9	
92	FL105	Fit Lining With Upper (Medium)		Man	1.42	2	**2.84**	15	1.9	
93	SE103	Top stitch large Elastic All around (Booty)		SNL	1.10	2	**2.20**	19	1.5	
94	SZ103	Zip Reinforcment Stitch		SNL	0.15	2	**0.30**	140	0.2	
95	ZS1	ZZ stifner seam + thread triming		ZZ	0.15	2	**0.30**	140	0.2	
96	CS1	Cement stiffner		Man	0.11	2	**0.22**	191	0.1	
97	CC101	Cement Counter Edge for fitting		Man	0.15	2	**0.30**	140	0.2	
98	FS1	Fit stiffner to back counter (Moccasin)		Man	0.22	2	**0.44**	95	0.3	
99	PN3	Repunch		MAN	0.03	2	**0.06**	700	0.0	
100	OT43	Strap Lacing		Man	0.25	2	**0.50**	84	0.3	
101	TT101	Toe Tacking		SNL	0.22	2	**0.44**	95	0.3	
102	TRL4	Trim Strap Lining		Trim	0.17	2	**0.34**	124	0.2	
103	TR113	Trim Fur Lining (Medium)		MAN	0.68	2	**1.36**	31	0.9	
104	TRT1	Thread triming + notch triming		Man	0.33	2	**0.66**	64	0.4	
105	BR1	Thread burning		MAN	0.23	2	**0.46**	91	0.3	
106	CL2	Cleaning (Hard) Mocassions, Strobbled, Sandles		Man	0.61	2	**1.22**	34	0.8	
107	OT1	Pairing & packing		Man	0.13	2	**0.26**	162	0.2	
108	cs1	Cement stiffner		Man	0.11	2	**0.22**	191	0.1	
109	fe1	Edge Fitting (Small)		Man	0.22	2	**0.44**	95	0.3	
110	FH2	Fit Heel Grip With Stiffener after Re Cement		Man	0.12	2	**0.24**	175	0.2	
111	TR106	Cut Elastic Lining(BOOTY)		MAN	0.12	2	**0.24**	175	0.2	
112	CS44	Cement for backer fitting(spot)	LOOP	Man	0.10	1	**0.10**	420	0.1	
113	FB1	Fit backer	LOOP	Man	0.15	1	**0.15**	280	0.1	
114	OT67	Cut		MAn	0.10	2	**0.20**	210	0.1	
115	TB101	Tack Buckle Loop		SNL	0.18	2	**0.36**	117	0.2	
116	TRL4	Trim Strap Lining	COLLAR	Trim	0.17	2	**0.34**	124	0.2	
117	OT49	Cement & past thread		Man	0.17	4	**0.68**	62	0.5	
118	OT112	Vamp Pairing		MAn	0.15	2	**0.30**	140	0.2	
119	OT111	Make Lining Sides		MAn	0.06	4	**0.24**	175	0.2	
		TOTAL					**66.66**		**45**	

PICTRUE / SKETCH

TARGET SUMMARY		
TOTAL S.A.M PER PAIR=	**66.66**	MINS.
ORDER QUANTITY=		PAIRS
PLANNED MANPOWER=	**45**	MEN
WORKING TIME=	**480**	MINS.
AVAILABLE MINUTES=	**21600**	MINS.
AVAILABLE HOURS=	**360**	HOURS
TARGET / HOUR	**41**	PAIRS
TARGET / SHIFT	**324**	PAIRS
TACK TIME (PITCH TIME)=	**1.48**	MINS.

4.3.6.2 ARTICLE # LB-2 (LONG BOOT)

FOOTWEAR	SEWING (CLOSING) OPERATION BREAK DOWN BOOTY	DATE

ARTICLE#:(UPDATED)	LB#2	CUSTOMER:	Caprice
CONSTRUCTION:	LASTED	LINE# / SECTION	L-1

SR #	Code	OPERATION	Description	M/C	SAM	FREQ	SAM PER PAIR	TGT PER HOUR	TH. MAN LVL
1	CS44	Cement for backer fitting(spot)		Man	0.11	2	0.22	191	0.1
2	OT6	Allign Backer (1 Component)		MAN	0.16	2	0.32	131	0.2
3	CS44	Cement for backer fitting(spot)		Man	0.11	10	1.10	38	0.7
4	OT6	Allign Backer (1 Component)		MAN	0.16	10	1.60	26	1.0
5	PR1	Rotary Press 1 Cycle		PRESS	0.51	3	1.53	27	1.0
6	OT95	Numbering	VAMP NUMBERING	MAn	0.10	2	0.20	210	0.1
7	TR101	Vamp Re-Trim		TRIM	0.17	2	0.34	124	0.2
8	TP12	Fit Tape To Toe		MAN	0.18	2	0.36	117	0.2
9	TP17	Toe Puff		PRESS	0.28	2	0.56	75	0.3
10	CE1	Edge Cementing (Small)	QTRS OUT SIDE & PC	Man	0.17	4	0.68	62	0.4
11	FE1	Edge Fitting (Small)	QTRS OUT SIDE & PC	Man	0.22	2	0.44	95	0.3
12	ST4	Top Stitch Straight	QTRS OUT SIDE PC	SNL	0.18	2	0.36	117	0.2
13	QB102	Quarter Back Seam (Small)	QTRS IN SIDE PC	SNL	0.20	2	0.40	105	0.2
14	TP8	Taping Quarter Front/ Bk Seam	QTRS IN SIDE PC	TAPE	0.15	2	0.30	140	0.2
15	JQ101	Join Qurter Bk/ Fornt Seam (Long)	FRONT	SNL	0.48	2	0.96	44	0.6
16	TP33	Fit Tape to Seam large Booty	FRONT	M/C	0.25	2	0.50	84	0.3
17	JQ101	Join Qurter Bk/ Fornt Seam (Long)	BACK	SNL	0.48	2	0.96	44	0.6
18	TP33	Fit Tape to Seam large Booty	BACK	M/C	0.25	2	0.50	84	0.3
19	PF5	Fit Fusing On Collar (Single Pc) Boots		Press	0.27	6	1.62	26	1.0
20	HE1	Elastic Hmmaering		M/C	0.09	2	0.18	233	0.1
21	CE101	Cement Elastic (Small)		Man	0.14	2	0.28	150	0.2
22	CE1	Edge Cementing (Small)	QTRS	Man	0.17	2	0.34	124	0.2
23	FE5	Fit Elastic Edge		Man	0.17	4	0.68	62	0.4
24	CC102	Cement Collar Edge For Folding		Man	0.31	4	1.24	34	0.8
25	FC102	Fold Collar Edge		Man	0.46	4	1.84	23	1.1
26	CV101	Cement Vamp Edge for fitting		Man	0.22	2	0.44	95	0.3
27	CU101	Cement Upper Edge For Vamp Fit		Man	0.22	2	0.44	95	0.3
28	FV101	Fit Vamp To Upper (Boots)		Man	0.61	2	1.22	34	0.8
29	ST8	Top Stitch Straight 1	VAMP	SNL	0.25	2	0.50	84	0.3
30	CE3	Edge Cementing (Large)	FRONT QTRS OUT SIDE	Man	0.33	2	0.66	64	0.4
31	CE3	Edge Cementing (Large)	BK QTRS IN SIDE	Man	0.33	2	0.66	64	0.4
32	FE3	Edge Fitting (Large)	QTRS OUT SIDE FIT	Man	0.45	2	0.90	47	0.6
33	ST11	Top Stitch Straight 2	QTRS OUT SIDE	SNL	0.35	2	0.70	60	0.4
34	SD10	Top Stitch Deco On Large Booty Collar & Zip	QTRS OUT SIDE DECO	SNL	0.52	2	1.04	40	0.6
35	TP15	Manual Taping Small	VAMP SIDE	MAN	0.13	6	0.78	54	0.5
36	CE1	Edge Cementing (Small)	QTRS INSIDE	Man	0.17	2	0.34	124	0.2
37	FE1	Edge Fitting (Small)	QTRS INSIDE	Man	0.22	2	0.44	95	0.3
38	TP9	Fit Nylon Tape To Straps		MAN	0.33	4	1.32	32	0.8
39	CS21	Cement Back Strap Edges		Man	0.11	2	0.22	191	0.1
40	FB101	Insert Buckle In Strap + Fold		Man	0.25	2	0.50	84	0.3
41	CS10	Cement Central strap (Small)		Man	0.13	2	0.26	162	0.2
42	CS36	Cement Back strap Lining (Small)		Man	0.13	2	0.26	162	0.2
43	FS12	Fit Back strap (small)		Man	0.19	2	0.38	111	0.2
44	SS15	Top stitch Back strap (Medium)	DNL	SNL	0.46	2	0.92	46	0.6
45	CS7	Cement Front strap (Small)		Man	0.13	2	0.26	162	0.2
46	CS30	Cement Front strap Lining (Small)		Man	0.13	2	0.26	162	0.2
47	FS6	Fit Front strap (small)		Man	0.19	2	0.38	111	0.2
48	SS7	Top stitch Front strap (Medium)	DNL	SNL	0.46	2	0.92	46	0.6
49	CE1	Edge Cementing (Small)		Man	0.17	2	0.34	124	0.2
50	OT105	Fold Zip		MAn	0.18	2	0.36	117	0.2
51	CZ101	Cement Zip (Long)		Man	0.39	2	0.78	54	0.5
52	CU102	Cement Upper For Zip Fit (Long)		Man	0.46	2	0.92	46	0.6
53	FZ101	Fit Zip (Large)		Man	0.88	2	1.76	24	1.1
54	OT17	Mark Zip For Trim		MAN	0.09	2	0.18	233	0.1
55	TR102	Trim Zip	RE-TRIM	MAN	0.07	2	0.14	300	0.1
56	CU104	Cement Straps To Fit With Upper		Man	0.11	4	0.44	95	0.3
57	CU105	Cement Upper For Strap Fitting		Man	0.11	4	0.44	95	0.3
58	FS103	Fit Strap With Upper		Man	0.17	4	0.68	62	0.4
59	SZ101	Top Stitch Zip Edge (Long)		SNL	0.93	2	1.86	23	1.2
60	ZQ102	Zig Zag Quarter Lining Front Seam(L)		ZZ	0.61	2	1.22	34	0.8
61	JQ105	Join Quarter Lining Bk Seam (Long)		SNL	0.60	2	1.20	35	0.7
62	JQ106	Join Qrter Lining With Vamp Lining		ZZ	0.28	2	0.56	75	0.3
63	TP14	Taping Vamp Zig Zag Seam		MAN	0.26	2	0.52	81	0.3
64	HV1	Hammering Vamp ZZ seam		M/C	0.24	2	0.48	88	0.3

65	ZL1	Zig Zag Lining Lock		ZZ	0.20	2	**0.40**	105	0.2	
66	CZ3	Cement Zip Cover Large		Man	0.22	2	**0.44**	95	0.3	
67	FZ105	Fit Zip Cover With Fur Lining Large		Man	0.22	2	**0.44**	95	0.3	
68	SZ105	Ts Zip Cover Piece (Long)		SNL	0.39	2	**0.78**	62	0.5	
69	OT67	Cut		MAn	0.10	3	**0.30**	160	0.2	
70	CL106	Cement Label		Man	0.09	3	**0.27**	178	0.2	
71	FL103	Fold & Fit Label		Man	0.13	3	**0.39**	123	0.2	
72	CL103	Cement Collr Pu Lining		Man	0.20	2	**0.40**	120	0.2	
73	FL101	Fit Pu Lining With Fur Lining		Man	0.22	2	**0.44**	109	0.3	
74	SC102	Ts Collar Pu Lining		SNL	0.26	4	**1.04**	46	0.6	
75	CH101	Cement Heel Grip		Man	0.15	2	**0.30**	160	0.2	
76	CL105	Cement Lining For Heel Grip Fitting		Man	0.20	2	**0.40**	120	0.2	
77	FH101	Fit Heel Grip With Lining		Man	0.22	2	**0.44**	109	0.3	
78	SH101	Ts Heel Grip		SNL	0.25	2	**0.50**	96	0.3	
79	CL101	Cement Lining Full (Long)		Man	0.73	2	**1.46**	33	0.9	
80	CU106	Cement Upper Full (Long)		Man	0.68	2	**1.36**	35	0.8	
81	FL102	Fit Lining With Upper (Long)		Man	1.76	2	**3.52**	14	2.2	
82	SZ106	Ts 2nd seam Zip & Collar All Around (L)		SNL	1.26	2	**2.52**	19	1.6	
83	SZ103	Zip Reinforcment Stitch		SNL	0.15	2	**0.30**	160	0.2	
84	TT101	Toe Tacking		SNL	0.22	2	**0.44**	109	0.3	
85	PN3	Repunch		MAN	0.03	8	**0.24**	200	0.1	
86	TR106	Cut Elastic Lining (BOOTY)		MAN	0.12	2	**0.24**	200	0.1	
87	TRL4	Trim Strap Lining		Trim	0.17	2	**0.34**	141	0.2	
88	OT43	Strap Lacing		Man	0.25	2	**0.50**	96	0.3	
89	TR105	Fur Lining Triming		MAN	0.87	2	**1.74**	28	1.1	
90	TR104	Collar Lining Triming		TRIM	0.30	2	**0.60**	80	0.4	
91	TRT1	Thread triming + notch triming		Man	0.33	2	**0.66**	73	0.4	
92	BR1	Thread burning		MAN	0.23	2	**0.46**	104	0.3	
93	CL107	Cleaning (Winter)		Man	1.41	2	**2.82**	17	1.8	
94	TT4	Tack	BUCKLE STRAP	SNL	0.20	2	**0.40**	120	0.2	
95	ZS1	ZZ stifner seam + thread triming		ZZ	0.15	2	**0.30**	160	0.2	
96	CS1	Cement stiffner		Man	0.11	2	**0.22**	218	0.1	
97	CU1	Cement upper back for back counter fitting		Man	0.22	2	**0.44**	109	0.3	
98	FC1	Fit counter to upper (moccasin)		Man	0.35	2	**0.70**	69	0.4	
99	CS1	Cement stiffner		Man	0.11	2	**0.22**	218	0.1	
100	FH1	Fit heel grip to back counter (moccasin)		Man	0.26	2	**0.52**	92	0.3	
101	OT112	Vamp Pairing		MAn	0.15	2	**0.30**	160	0.2	
102	OT111	Make Lining Sides		MAn	0.06	4	**0.24**	200	0.1	
103	HS8	Hammering Seam Qtrs Long Booty		MAN	0.50	2	**1.00**	48	0.6	
104	OT49	Cement & past thread		Man	0.17	4	**0.68**	71	0.4	
105	OT1	Pairing & packing		Man	0.13	2	**0.26**	185	0.2	
		TOTAL					**72.21**		**45**	

PICTRUE / SKETCH

TARGET SUMMARY

TOTAL S.A.M PER PAIR=	**72.21**	MINS.
ORDER QUANTITY=		PAIRS
PLANNED MANPOWER=	**45**	MEN
WORKING TIME=	**480**	MINS.
AVAILABLE MINUTES=	**21600**	MINS.
AVAILABLE HOURS=	**360**	HOURS
TARGET / HOUR	**37**	PAIRS
TARGET / SHIFT	**299**	PAIRS
TACK TIME (PITCH TIME)=	**1.60**	MINS.
CPM=		PKR

4.3.7 Operational Breakdown for MOCCASIN

4.3.6.3 ARTICLE # MOCC-1 (MOCCASIN)

FOOTWEAR	SEWING (CLOSING) OPERATION BREAK DOWN	DATE

ARTICLE#:(UPDATED)	Mocc#1	CUSTOMER:	CAPRICE
CONSTRUCTION:	Moccasin	LINE# / SECTION	L-1

SR #	Code	OPERATION	Description	M/C	SAM	FREQ	SAM PER PAIR	TGT PER HOUR	TH. MAN LVL	
1	PF1	Fit & Press fusing on Apparon Edge (WJ-150)		Press	0.55	2	1.10	38	1.4	
2	PF2	Fit & Press fusing on Vamp Edge (WJ-150)		Press	0.55	2	1.10	38	1.4	
3	CS44	Cement for backer fitting(spot)		Man	0.11	6	0.66	64	0.8	
4	OT6	Allign Backer (1 Component)		MAN	0.16	6	0.96	44	1.2	
5	PR1	Rotary Press 1 Cycle		PRESS	0.51	1	0.51	82	0.6	
6	PF6	Press Fusing	COLLAR	Press	0.28	4	1.12	38	1.4	
7	JC1	Join back counter seam		SNL	0.25	2	0.50	84	0.6	
8	TP2	Fit tape to counter seam		Tape	0.13	2	0.26	162	0.3	
9	ZS1	ZZ stifner seam + thread triming		ZZ	0.15	2	0.30	140	0.4	
10	CS1	Cement stiffner		Man	0.11	2	0.22	191	0.3	
11	CC1	Cement counter For Stiffener Fit		Man	0.13	2	0.26	162	0.3	
12	CC2	Cement counter edge to fit with upper		Man	0.19	2	0.38	111	0.5	
13	CU1	Cement upper back for back counter fitting		Man	0.22	2	0.44	95	0.5	
14	FC1	Fit counter to upper (moccasin)		Man	0.35	2	0.70	60	0.9	
15	SC3	Top stitch counter 2 sided		DNL	0.39	4	1.56	27	1.9	
16	CE1	Edge Cementing (Small)	COLLAR + PC	Man	0.17	2	0.34	124	0.4	
17	FE1	Edge Fitting (Small)	COLLAR + PC	Man	0.22	2	0.44	95	0.5	
18	SC9	Top Stitch Collar Join		SNL	0.17	2	0.34	124	0.4	
19	PN3	Repunch	COLLAR	MAN	0.03	16	0.48	88	0.6	
20	PN2	Eyeletting Collar piece (8 holes)		Snap	0.39	2	0.78	54	1.0	
21	OT2	Collar lacing (8 holes)		Man	0.67	2	1.34	31	1.6	
22	OT19	Trim Lacing+Paste		Man	0.28	2	0.56	75	0.7	
23	ZA1	ZZ Apron Lining		ZZ	0.16	2	0.32	131	0.4	
24	TP6	Fit Tape to Apron zig zag seam		Man	0.13	2	0.26	162	0.3	
25	HA1	Hammering Appron ZZ seam		M/C	0.11	2	0.22	191	0.3	
26	ZV1	ZZ Vamp Lining		ZZ	0.32	2	0.64	66	0.8	
27	TP7	Fit Tape to Vamp zig zag seam		Man	0.22	2	0.44	95	0.5	
28	HV1	Hammering Vamp ZZ seam		M/C	0.24	2	0.48	88	0.6	
29	OT40	Cut ribbon		Man	0.07	4	0.28	150	0.3	
30	CE101	Cement Elastic (Small)		Man	0.14	4	0.56	75	0.7	
31	CA1	Cement Appron / vamp edge for fitting	ELASTIC	MAN	0.17	4	0.68	62	0.8	
32	FE5	Fit Elastic Edge	APRON	Man	0.17	4	0.68	62	0.8	
33	CR1	Cement Ribbon		Man	0.11	4	0.44	95	0.5	
34	FR1	Fit Ribbon		Man	0.08	4	0.32	131	0.4	
35	SP1	Spray apron/Lining		Man	0.11	4	0.44	95	0.5	
36	FL2	Fit Lining to apron		Man	0.26	2	0.52	81	0.6	
37	ST1	Top stitch tongue edge	DNL	SNL	0.28	2	0.56	75	0.7	
38	CH1	Cement heel grip		Man	0.13	2	0.26	162	0.3	
39	CV2	Cement Vamp Lining Edge		Man	0.22	2	0.44	95	0.5	
40	FH1	Fit heel grip to back counter (moccasin)		Man	0.26	2	0.52	81	0.6	
41	SH101	Ts Heel Grip		SNL	0.25	2	0.50	84	0.6	
42	SP2	Spray Vamp/vamp lining		Man	0.17	4	0.68	62	0.8	
43	FL3	Fit Lining to vamp (moccasin)		Man	0.61	2	1.22	34	1.5	
44	JC2	Join collar strap with upper		SNL	0.51	2	1.02	41	1.3	
45	CU2	Cement Upper & collar for folding (Whole)		Man	0.46	2	0.92	46	1.1	
46	FC3	Fold collar		Man	0.61	2	1.22	34	1.5	
47	SC5	Top stitch collar bottom edge		SNL	0.44	2	0.88	48	1.1	
48	CE4	Close Elastic End		SNL	0.33	4	1.32	32	1.6	
49	PN8	Repunch Apparon		MAN	0.01	92	0.92	46	1.1	
50	PN9	Repunch Vamp		MAN	0.01	92	0.92	46	1.1	
51	TRL1	Trim counter lining		Man	0.37	2	0.74	57	0.9	
52	TRL3	Trim Upper Lining		Trim	0.30	2	0.60	70	0.7	
53	TRL2	Trim apron lining		Trim	0.21	2	0.42	100	0.5	
54	TRT1	Thread triming + notch triming		Man	0.33	2	0.66	64	0.8	
55	BR1	Thread burning		MAN	0.23	2	0.46	91	0.6	
56	CL1	Cleaning (Regular) Mocassions, Strobbled, Sa		Man	0.39	2	0.78	54	1.0	
57	OT1	Pairing & packing		Man	0.13	2	0.26	162	0.3	
58	FE5	Fit Elastic Edge	VAMP	Man	0.17	4	0.68	62	0.8	
		TOTAL					36.61			

PICTRUE / SKETCH	TARGET SUMMARY		
	TOTAL S.A.M PER PAIR=	**36.61**	MINS.
	ORDER QUANTITY=		PAIRS
	PLANNED MANPOWER=	**45**	MEN
	WORKING TIME=	**480**	MINS.
	AVAILABLE MINUTES=	**21600**	MINS.
	AVAILABLE HOURS=	**360**	HOURS
	TARGET / HOUR	**74**	PAIRS
	TARGET / SHIFT	**590**	PAIRS
	TACK TIME (PITCH TIME)=	**0.81**	MINS.

4.3.6.4 ARTICLE # MC-2 (MOCCASIN)

FOOTWEAR

SERVICE INDUSTRIES LIMITED

(10 KM MURIDKE SHEIKHUPURA ROAD, MURIDKE)

SEWING (CLOSING) OPERATION BREAK DOWN

DATE

ARTICLE#:(UPDATED)	MOCC#2	**CUSTOMER:**	CAPRICE
CONSTRUCTION:	MOCCASIN	**LINE# / SECTION**	L-1

SR #	Code	OPERATION	Description	M/C	SAM	FREQ	SAM PER PAIR	TGT PER HOUR	TH. MAN LVL	
1	PF1	Fit & Press fusing on Apparon Edge (WJ-150)		Press	0.55	2	**1.10**	38	1.2	
2	PF2	Fit & Press fusing on Vamp Edge (WJ-150)		Press	0.55	2	**1.10**	38	1.2	
3	CS44	Cement for backer fitting(spot)		Man	0.11	6	**0.66**	64	0.7	
4	OT6	Allign Backer (1 Component)		MAN	0.16	6	**0.96**	44	1.1	
5	PR1	Rotary Press 1 Cycle		PRESS	0.51	1	**0.51**	82	0.6	
6	PF3	Fit & Fusing To Collar strap		Press	0.39	2	**0.78**	54	0.9	
7	PE1	Press Eyeletstay	VAMP EDGES	PRESS	0.28	4	**1.12**	38	1.3	
8	ZA1	ZZ Apron Lining		ZZ	0.16	2	**0.32**	131	0.4	
9	TP6	Fit Tape to Apron zig zag seam		Man	0.13	2	**0.26**	162	0.3	
10	HA1	Hammering Appron ZZ seam		M/C	0.11	2	**0.22**	191	0.2	
11	ZV1	ZZ Vamp Lining		ZZ	0.32	2	**0.64**	66	0.7	
12	TP7	Fit Tape to Vamp zig zag seam		Man	0.22	2	**0.44**	95	0.5	
13	HV1	Hammering Vamp ZZ seam		M/C	0.24	2	**0.48**	88	0.5	
14	SP1	Spray apron/Lining		Man	0.11	4	**0.44**	95	0.5	
15	FL2	Fit Lining to apron		Man	0.26	2	**0.52**	81	0.6	
16	PL2	Press Apparon lining		Press	0.18	2	**0.36**	117	0.4	
17	ST1	Top stitch tongue edge		SNL	0.28	2	**0.56**	75	0.6	
18	SP2	Spray Vamp/vamp lining		Man	0.17	4	**0.68**	62	0.8	
19	FL3	Fit Lining to vamp (moccasin)		Man	0.61	2	**1.22**	34	1.4	
20	PL1	Press Vamp lining		Press	0.35	2	**0.70**	60	0.8	
21	CS1	Cement stiffner		Man	0.11	2	**0.22**	191	0.2	
22	CC1	Cement counter For Stiffener Fit		Man	0.13	2	**0.26**	162	0.3	
23	FS1	Fit stiffner to back counter (Moccasin)		Man	0.22	2	**0.44**	95	0.5	
24	CC2	Cement counter edge to fit with upper		Man	0.19	2	**0.38**	111	0.4	
25	CU1	Cement upper back for back counter fitting		Man	0.22	2	**0.44**	95	0.5	
26	FC1	Fit counter to upper (moccasin)		Man	0.35	2	**0.70**	60	0.8	
27	CH1	Cement heel grip		Man	0.13	2	**0.26**	162	0.3	
28	CC3	Cement back for heel grip fitting		Man	0.17	2	**0.34**	124	0.4	
29	FH1	Fit heel grip to back counter (moccasin)		Man	0.26	2	**0.52**	81	0.6	
30	SC3	Top stitch counter 2 sided		DNL	0.39	2	**0.78**	54	0.9	
31	JC2	Join collar strap with upper		SNL	0.51	2	**1.02**	41	1.1	
32	CU2	Cement Upper & collar for folding (Whole)		Man	0.46	2	**0.92**	46	1.0	
33	FC3	Fold collar		Man	0.61	2	**1.22**	34	1.4	
34	SC5	Top stitch collar bottom edge		SNL	0.44	2	**0.88**	48	1.0	
35	OT41	Mark Rivet		Man	0.01	114	**1.14**	37	1.3	
36	PN10	Punch Deco Trims (4-legs)		MAN	0.07	114	**7.98**	5	9.0	
37	CT1	Cement tie piece	TIE & LINING	MAN	0.17	4	**0.68**	62	0.8	
38	FL5	Fit Tie Lining+numbering		Man	0.22	2	**0.44**	95	0.5	
39	PL3	Press tie lining		Press	0.18	2	**0.36**	117	0.4	
40	PN8	Repunch Apparon		MAN	0.01	90	**0.90**	47	1.0	
41	PN9	Repunch Vamp		MAN	0.01	90	**0.90**	47	1.0	
42	PN5	Repunch Holes For hand Stitching	TIE	MAN	0.01	40	**0.40**	105	0.4	
43	TRL1	Trim counter lining		Man	0.37	2	**0.74**	57	0.8	
44	TRL2	Trim apron lining		Trim	0.21	2	**0.42**	100	0.5	
45	TRL4	Trim Strap Lining		Trim	0.17	2	**0.34**	124	0.4	

46	TRT1	Thread triming + notch triming	TIE	Man	0.33	2	**0.66**	64	0.7	
47	BR1	Thread burning		MAN	0.23	2	**0.46**	91	0.5	
48	CL1	Cleaning (Regular) Mocassions, Strobbled, Sandles		Man	0.39	2	**0.78**	54	0.9	
49	HC1	Hammering collar seam		M/C	0.36	2	**0.72**	58	0.8	
50	HC1	Hammering collar seam		M/C	0.36	2	**0.72**	58	0.8	
51	PN3	Repunch	COLLAR	MAN	0.03	12	**0.36**	117	0.4	
52	TRL6	Trim Lining		MAN	0.17	2	**0.34**	124	0.4	
53	OT1	Pairing & packing		Man	0.13	2	**0.26**	162	0.3	
TOTAL							**40.05**			

PICTRUE / SKETCH	TARGET SUMMARY		
	TOTAL S.A.M PER PAIR=	40.05	MINS.
	ORDER QUANTITY=		PAIRS
	PLANNED MANPOWER=	45	MEN
	WORKING TIME=	480	MINS.
	AVAILABLE MINUTES=	21600	MINS.
	AVAILABLE HOURS=	360	HOURS
	TARGET / HOUR	67	PAIRS
	TARGET / SHIFT	539	PAIRS
	TACK TIME (PITCH TIME)=	0.89	MINS.

Now the project team has prepared 2 operational breakdowns, 2 for long boot articles & 2 for moccasin articles. Project team have also calculated targets for these articles based on the standard allowed minutes (SAM) which we have already calculated. These targets are based on 45 workers which is the fixed manpower of closing line for the respective organization.

According to the operational breakdown, we have observed the average operations for long boots articles are 100 operations per article which means that each worker has to perform 2 operations & as far as Moccasin is concerned the average operations observed for moccasin articles is about 45 operations, which means according to the fix manpower of 45 for each closing line 1 operations/worker will be its format.

COMBINATION	1	2	3	4	5	6	7	8	9	10	11	12
Article 1	Mocc # 1	LB # 1	Mocc # 2	LB # 2	Mocc # 1	Mocc # 2	LB # 1	LB # 2	Mocc # 2	Mocc # 1	LB # 2	LB # 1
Article 2	LB # 1	Mocc # 2	LB # 2	Mocc # 1	Mocc # 2	LB # 1	LB # 2	Mocc # 2	Mocc # 1	LB # 2	LB # 1	Mocc # 1

Figure 27 Moccasin vs. Long Changeover Combinations

Now project team has prepared 12 combinations for moccasin & long boot articles for experimental run & system analysis.

4.3.8 TARGET vs. LOST PAIRS ANALYSIS

Now after presentation of team's previous working management has decided to provide the 2-closing lines to team for our rest of data collection activities experimentation. Now team will be focusing to run these articles as per previous practices & try to find out the actual efficiency of these long boots& moccasin articles running individually & in combination of moccasin &long boot. This step will help us in finding out the line losses & respective productivity losses.

Productivity analysis will be done using **Control Charts**. Control charts are set of methods for monitoring process characteristics over time and place these tools in the wider perspective of process improvement. Control charts deals more generally with changes in a variable over time.

Now in first phase team will be running long boot& moccasin article individually to check out its actual production & efficiency.

4.3.8.1 MOCCASIN TARGET vs. LOST PAIRS ANALYSIS

CLOSING SECTION LOST PAIRS ANALYSIS

LINE # ⇨	Analysis 1	Analysis 2	Analysis 3	Analysis 4	Analysis 5	Analysis 6	Analysis 7	Analysis 8	Analysis 9	Analysis 10	Analysis 11	SUMMARY	
ARTICLES	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	Mocc.	11	(TTL # OF ARTS.)
SAM OF ARTICLE	37.34	37.34	32.69	29.79	24.26	32.13	34.75	32.88	35.95	33.64	37.54	33	(AVG. SAM)
ACTUAL OUTPUT	400	400	400	400	400	400	400	400	400	400	400	350	(AVG. OUTPUT/LINE)
HOURS WORKED	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	9.50 9.50	570	(AVG. MINs. WORKED)
AVAIL. M/PWR.	45	45	45	45	45	45	45	45	45	45	45	45	(AVG AVL. MANPWR)
AVAIL. M/PWR.	45	45	45	45	45	45	45	45	45	45	45	45	(AVG M/PWR. PER LINE)
AVAIL. MINs.	25650	25650	25650	25650	25650	25650	25650	25650	25650	25650	25650	25650	(AVG AVL MINS.)
ERND. MINs.	14936	14936	13076	11916	9704	12852	13900	13152	14380	13456	15016	13393	(AVG ERND. MINS.)
AGG. SAM.	43	43	37	34	28	37	40	38	41	38	43	38	(AVG.AGGREGATE SAM)
TGT @ 100%	601	601	687	753	925	699	646	683	624	667	598	680	(100% AVG TGT PAIRS)
TGT @ 80%	481	481	549	603	740	559	517	546	499	534	478	544	(80% AVGTGT PAIRS)
# OF ARTICLES	1	1	1	1	1	1	1	1	1	1	1	1	(AVG # of ARTICLES)
LOST MINS	10714	10714	12574	13734	15946	12798	11750	12498	11270	12194	10634	12257	(AVG LOST MINs.)
LOST PAIRS	251	251	337	403	575	349	296	333	274	317	248	330	(AVG. LOST PAIRS)
OUTPUT	350	350	350	350	350	350	350	350	350	350	350	350	(AVG. OUTPUT PAIRS)
EFFICIENCY	58%	58%	51%	46%	38%	50%	54%	51%	56%	52%	59%	52%	(AVG EFFICIENCY)
LOST PAIRS%	42%	42%	49%	54%	62%	50%	46%	49%	44%	48%	41%	48%	(AVG LOST PAIRS %)

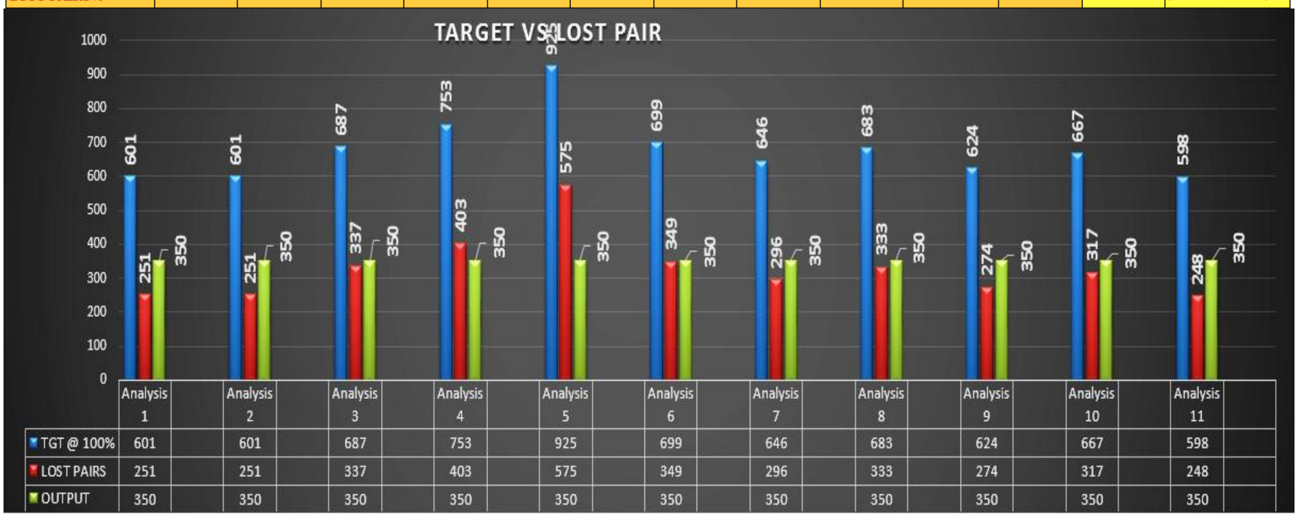


Figure 28 MOCCASIN TARGET vs. LOST PAIRS ANALYSIS

Team has found that targets for moccasin & long boots are fixed based on Lasting lines (Lines where sole is attached with upper) they need to have **400 pairs/day** output for moccasin article &**250 pairs/day** output for long boots to run their lasting lines at their full capacity. So as per above analysis the shift time being conducted by closing lines is 9.50 hours i.e. 8:00 a.m. to 6:00 p.m.

After formulation of moccasin target vs. lost pair analysis, team have concluded that working on the basis of pre-developed SAM data bank aggregate SAM for moccasin article is **38 min**, average lost minutes are **12257 minutes/day** relative to **25650** available minutes/day**,** average number of lost pairs are about **330 pairs/day** relative to **680 pairs/day** target& percentage of lost pairs on average is about **48%** relative to **target/day**.

4.3.8.2 LONG BOOT TARGET vs. LOST PAIRS ANALYSIS

SEWING SECTION LOST PAIRS ANALYSIS

LINE # ⇨	Analysis 1		Analysis 2		Analysis 3		Analysis 4		Analysis 5		Analysis 6		Analysis 7		Analysis 8		Analysis 9		Analysis 10		Analysis 11		SUMMARY	
ARTICLES	LB		LB		LB		LB		LB		LB		LB		LB		LB		LB		LB		11	(TTL # OF ARTS.)
SAM OF ARTICLE	51.54		66.40		71.95		64.67		57.91		48.32		51.88		52.93		67.82		65.38		57.10		60	(AVG. SAM)
ACTUAL OUTPUT	250		200		200		200		200		250		250		200		200		200		250		218	(AVG. OUTPUT/LINE)
HOURS WORKED	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	52	(AVG. MINs. WORKED)
AVAIL. M/PWR.	45		45		45		45		45		45		45		45		45		45		45		495	(TOTAL AVL. MANPWR)
AVAIL. M/PWR.	45		45		45		45		45		45		45		45		45		45		45		45	(AVG M/PWR. PER LINE)
AVAIL. MINs.	25650		25650		25650		25650		25650		25650		25650		25650		25650		25650		25650		25650	(AVG AVL MINS.)
ERND. MINs.	12885		13280		14390		12934		11582		12080		12970		10586		13564		13076		14275		12875	(AVG ERND. MINS.)
AGG. SAM.	52		66		72		65		58		48		52		53		68		65		57		60	(AGGREGATE SAM)
TGT @ 100%	498		386		356		397		443		531		494		485		378		392		449		437	(100%TGT PAIRS TTL)
TGT @ 80%	398		309		285		317		354		425		396		388		303		314		359		350	(80%TGT PAIRS TTL)
# OF ARTICLES	1		1		1		1		1		1		1		1		1		1		1		1	(AVG # of ARTICLES)
LOST MINS	12765		12370		11260		12716		14068		13570		12680		15064		12086		12574		11375		12775	(AVG LOST MINs.)
LOST PAIRS	248		186		156		197		243		281		244		285		178		192		199		219	(AVG LOST PAIRS)
OUTPUT	250		200		200		200		200		250		250		200		200		200		250		218	(AVG OUTPUT PAIRS)
EFFICIENCY	50%		52%		56%		50%		45%		47%		51%		41%		53%		51%		56%		50%	(AVG EFFICIENCY)
LOST PAIRS%	50%		48%		44%		50%		55%		53%		49%		59%		47%		49%		44%		50%	(AVG EFFICIENCY)

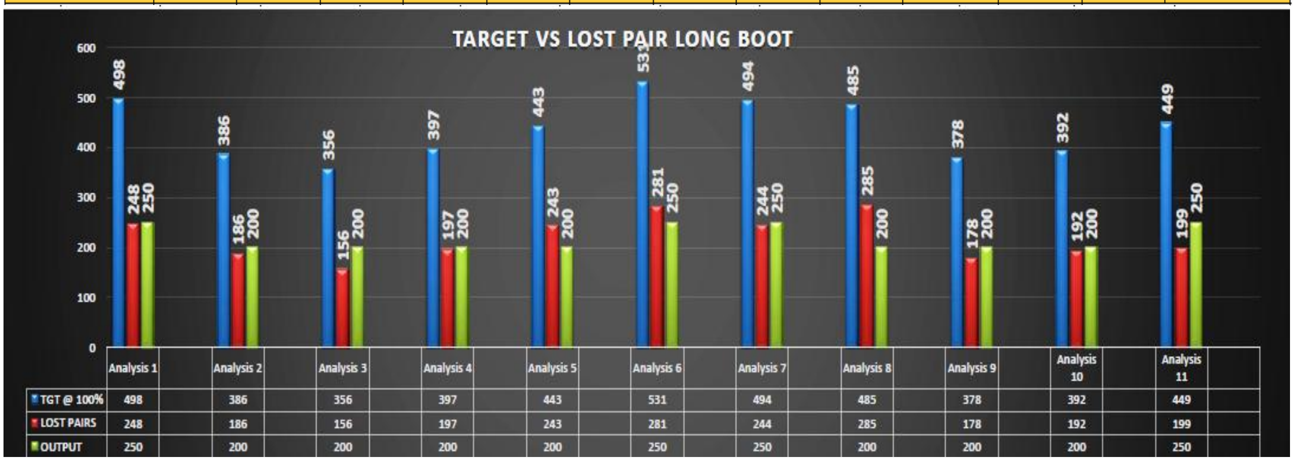


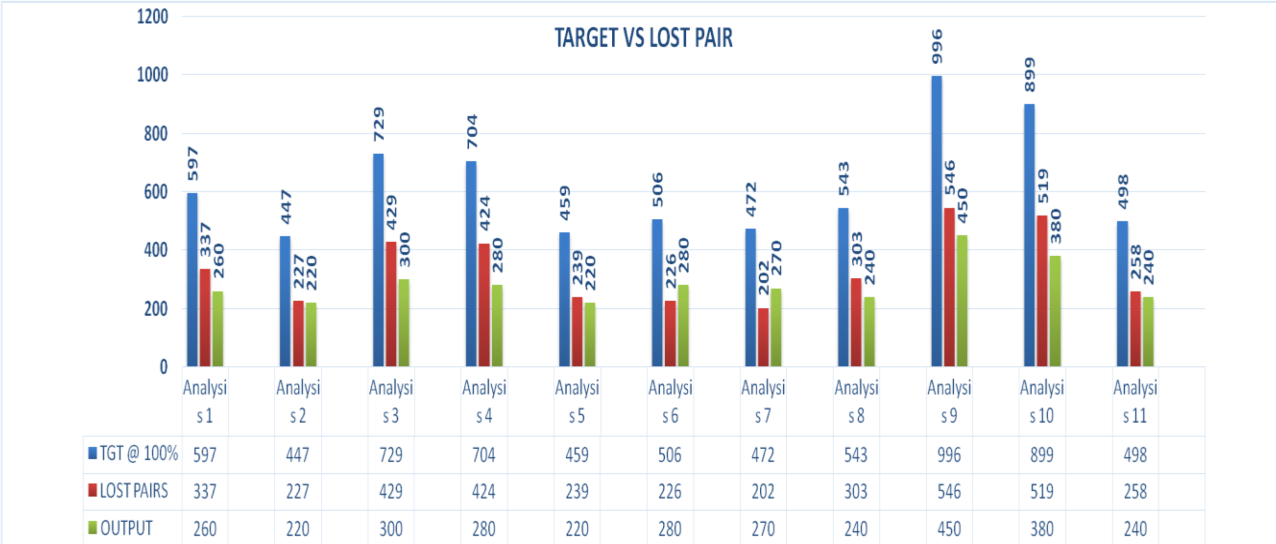
Figure 29 LONG BOOT TARGET vs. LOST PAIRS ANALYSIS

After formulation of long boot target vs. lost pair analysis, team have concluded that working on the basis of pre-developed SAM data bank aggregate SAM for long boot article is 5**9 minutes**, average lost minutes are **12775 minutes/day** relative to **25650** available minutes/day**,** average number of lost pairs are about **200 pairs/day** relative to **437 pairs/day** target & percentage of lost pairs on average is about **50%** relative to **target/day**.

4.3.8.3 LONG BOOT& MOCCASIN CHANGEOVER TARGET vs. LOST PAIRS ANALYSIS

SEWING SECTION LOST PAIRS ANALYSIS

LINE # ⇨	Analysis 1		Analysis 2		Analysis 3		Analysis 4		Analysis 5		Analysis 6		Analysis 7		Analysis 8		Analysis 9		Analysis 10		Analysis 11		SUMMARY	
ARTICLES	MOCC	LONG BOOT	LONG BOOT	LONG BOOT	LONG BOOT	MOCC	MOCC	MOCC	MOCC	LONG BOOT	LONG BOOT	MOCC	MOCC	LONG BOOT	LONG BOOT	MOCC	MOCC	MOCC	MOCC	MOCC	MOCC	LONG BOOT	22	(TTL # OF ARTS.)
SAM OF ARTICLE	36.61	64.24	64.24	51.76	51.76	29.13	29.13	37.34	37.34	71.24	71.24	32.88	32.88	81.11	81.11	35.95	35.95	22.84	22.84	33.64	33.64	69.33	47	(AVG. SAM)
ACTUAL OUTPUT	200	60	100	120	80	220	30	250	100	120	130	150	150	120	60	180	100	350	180	200	120	120	285	(AVG. OUTPUT/LINE)
HOURS WORKED	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	52	(AVG. MINs. WORKED)
AVAIL. M/PWR.	45		45		45		45		45		45		45		45		45		45		45		495	(TOTAL AVL. MANPWR)
AVAIL. M/PWR.	45		45		45		45		45		45		45		45		45		45		45		45	(AVG M/PWR. PER LINE)
AVAIL. MINs.	25650		25650		25650		25650		25650		25650		25650		25650		25650		25650		25650		25650	(AVG AVL MINS.)
ERND. MINs.	11176		12635		10549		10209		12283		14193		14665		11338		11589		10839		12356		11985	(AVG ERND. MINS.)
AGG. SAM.	43		57		35		36		56		51		54		47		26		29		51		44	(AVG.AGGREGATE SAM)
TGT @ 100%	597		447		729		704		459		506		472		543		996		899		498		623	(100% AVG TGT PAIRS)
TGT @ 80%	477		357		584		563		368		405		378		434		797		719		399		498	(80% AVGTGT PAIRS)
# OF ARTICLES	2		2		2		2		2		2		2		2		2		2		2		2	(AVG # of ARTICLES)
LOST MINS	14474		13015		15101		15441		13367		11457		10985		14312		14061		14811		13294		13665	(AVG LOST MINs.)
LOST PAIRS	337		227		429		424		239		226		202		303		546		519		258		337	(AVG. LOST PAIRS)
OUTPUT	260		220		300		280		220		280		270		240		450		380		240		290	(AVG. OUTPUT PAIRS)
EFFICIENCY	44%		49%		41%		40%		48%		55%		57%		44%		45%		42%		48%		47%	(AVG EFFICIENCY)
LOST PAIRS%	56%		51%		59%		60%		52%		45%		43%		56%		55%		58%		52%		53%	(AVG LOST PAIRS %)



	Analysis 1	Analysis 2	Analysis 3	Analysis 4	Analysis 5	Analysis 6	Analysis 7	Analysis 8	Analysis 9	Analysis 10	Analysis 11
TGT @ 100%	597	447	729	704	459	506	472	543	996	899	498
LOST PAIRS	337	227	429	424	239	226	202	303	546	519	258
OUTPUT	260	220	300	280	220	280	270	240	450	380	240

Figure 30 LONG BOOT& MOCCASIN CHANGEOVER TARGET vs. LOST PAIRS ANALYSIS

After formulation of long boot & moccasin changeover target vs. lost pair analysis, team have concluded that working on the basis of pre-developed SAM data bank aggregate SAM for long boot & moccasin combination articles is **45 minutes**, average lost minutes are **13665 minutes/day** relative to **25650** available **minutes/day,** average number of lost pairs are about **337 pairs/day** relative to **623 pairs/day** target & percentage of lost pairs on average is about **53%** relative to **target/day**.

4.3.9 ANALYSIS OF SYSTEM CAPABILITY

Aim of this section is to draw an analysis over the actual efficiency of the current system and how much this system can be improved after the implementation of DMAIC.

So this lost pair & efficiency analysis will be the key formulation for the project team & management to analyze the system performance before & after systematic changes.

Now from the above target vs. loss pair analysis it's quite clear that closing lines are providing less production than their actual capacity. As we have seen by the three different experiments according to the current system, in each of three processes the closing lines were producing less quantity because of systematic problems.

So the project team has concluded that team will be focusing over the process to improve the efficiency& productivity of the line, because it's the process that is the main reason behind the low production and not the product.

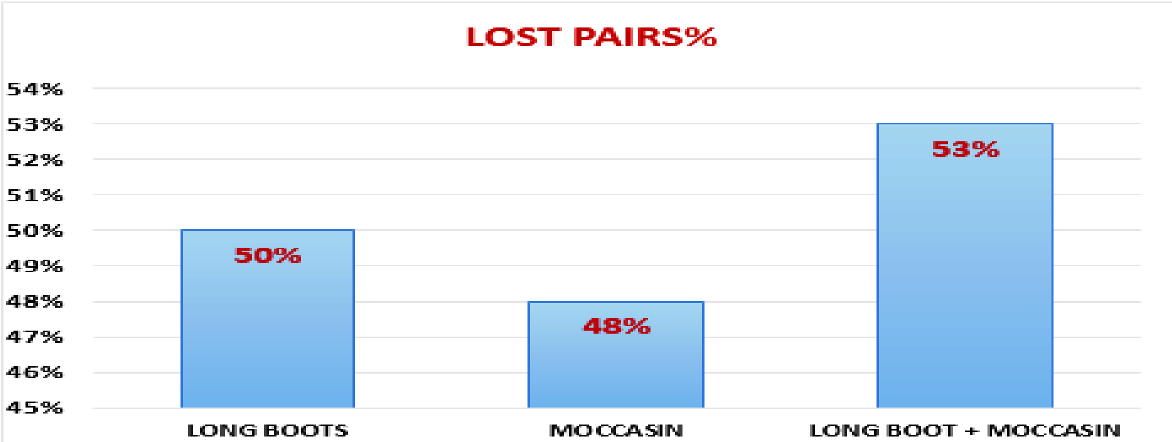


Figure 31 LOST PAIR ANALYSIS

The above graph presents the situation of the low performance of the system after experiments performed with the current criteria of production process & defining targets. Graph also represents that there is a lot of capability in the system for improvement.

4.4 ANALYSE PHASE

The next phase of the DMAIC methodology is Analyze. In this phase, we want to identify excessive sources of variation, search for the factors that have the biggest impacts on process performance and determine the root cause of problems. According to Pande (2004), there are three ways to analyze the roots cause of problems:

1. Exploring: Investigate data and the process with an open mind to see what can be learned from them.
2. Create hypothesis about the causes: Use new knowledge to identify the causes that produce more defects.
3. Verify or eliminated the causes: Use data or a more detailed analysis of the process to check which of the causes contribute the most to the problem. The tools used are:

	Data Analysis	Process Analysis
Explore	Examine in diferent ways, the data taken from the Measurement phase **Tools:** Pareto Graph Histograms	Create a process map which reflects what the actual process looks like. **Tools:** Basic Flowchart
Hypothesis Generation	Utilized everything learned to generate ideas about defects in the process. **Tools:** Brainstorming Ishikawa Diagram	Use flowcharts to identify areas in which phases of of the process are not clear **Tools:** Brainstorming
Cause verification	Gather aditional data to check if hypothesis are true **Tools:** Dispersion diagram	Gather new data to cuantify the loss in time in some stages of the process **Tools:** Flowchart map Value stream mapping

Figure 32 Data vs. Process Analysis

As we have accurate material data from the process for our analysis we will not be going into hypothesis testing and rather using real-time data to do changes or study improvements.

4.4.1 Ishikawa Diagram

It is a tool used in analyze phase. Project team members in the group did a brainstorming session to see which major causes contribute to the low productivity and these ideas were classified according to the 5M's presented in the Ishikawa diagram.

This diagram is an excellent tool for the group to think about possible causes of the problem, establishing different categories helps the group focus on several possibilities than just a few ones. It also helps to initialize the Analyze phase of the DMAIC methodology.

For the low productivity, most causes are presented in the each category. These were some of the causes mentioned by all team members.

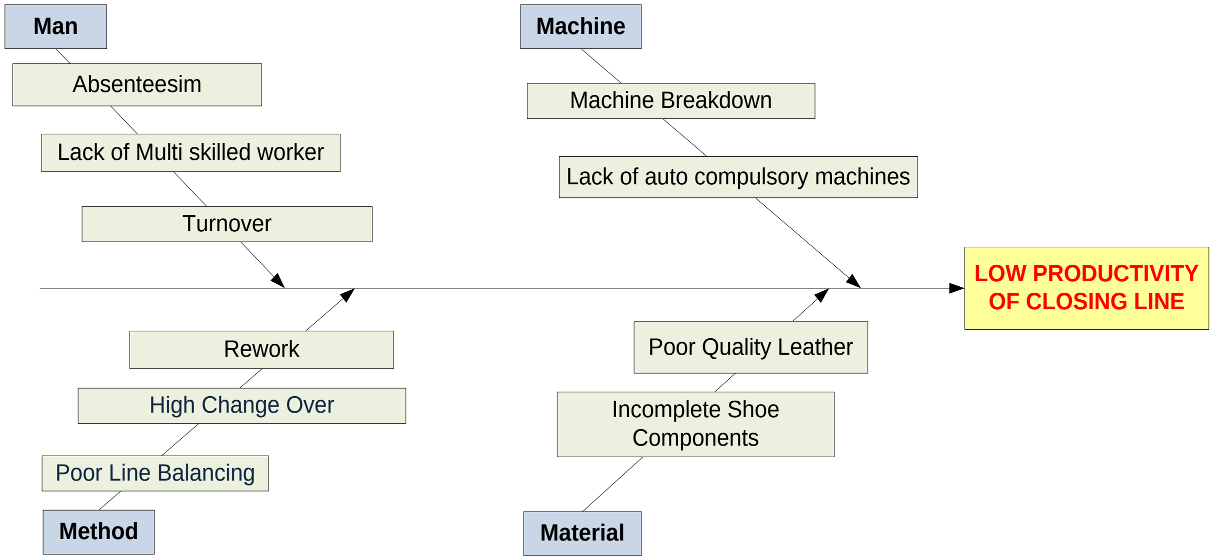


Figure 33 ISHIKAWA Diagram

After doing the Ishikawa Diagram, project team have meeting on which causes they thought becoming the real cause for low productivity of closing lines!! From team's point of view the High changeover & Poor line balancing are the real cause of low productivity of closing lines.
For production optimization of the closing line we will concentrate on reducing changeover time & improve line balancing technique.

4.4.2 Prioritization Tool (verification of causes)

It's a very simple tool in which all the potential causes that have been verified are categorized and sorted very systematically. The main aim of the tool is to help in implementation of solutions and increasing chances of success of the solutions suggested.
Rather than jumping directly to solving all the problems identified we first categorize them in terms of how much impact solving a certain problem will have on the process and how controllable is the cause.
The graphical form of the data analyzed is attached below we can clearly see that it has sorted out the causes that can be removed easily and with a larger impact in improving the process capability. And what causes we should explore more and what should be ignored.
The problems in the green region need to be handled first and then if possible we work on problems in the yellow region. But in order to meet the time and target constraints we ignore or do not verify the causes that fall in the difficult to control and low impact red zone such as Poor quality leather, labor turnover, Lack of compulsory machines. We also ignore the causes in the lower yellow portion that are easy to control but have very insignificant effect or impact such as absenteeism & incomplete shoe component. The main outcome of this step of analyze phase is that it increases efficiency of DMAIC and saves the wastage of resources and efforts.

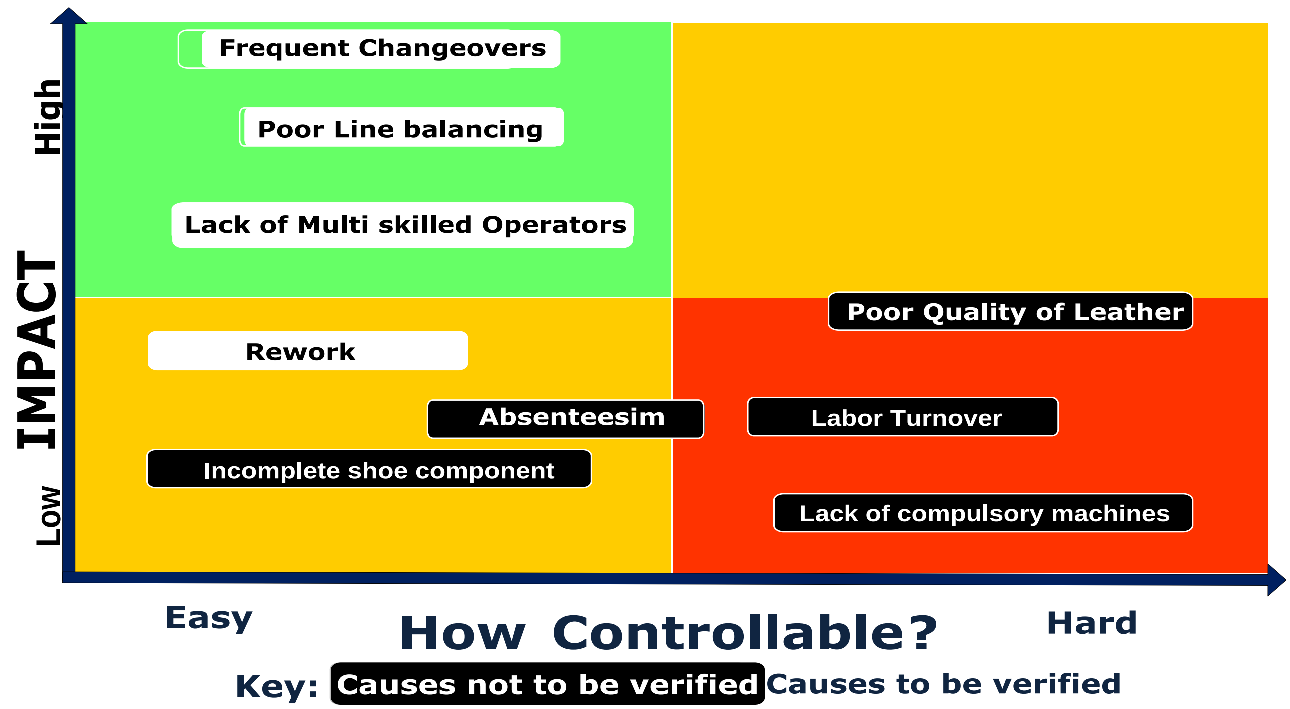


Figure 34 Prioritization Tool

4.4.3 Plan for Cause verification

Now that we have established a theory about what might be the causes of the productivity losses and also have categorized them in terms of effects and controllability.

The next step taken was to devise an action plan that could be used to verify the causes. And ensure that the problems were because of the causes we have identified. In this phase we test our hypothesis about causes by devising a plan to verify them.

The table below shows the causes and there plan for verification using different techniques and practical data. The results are also shared in the last column that tells if the cause was verified or not.

Potential Causes Xs	Theory About Impact	How To Verify The Theory (Including data & Tool)	Status
Frequent Changeovers	Due to small order quantities the rate of changeover is high & current "U" shape layout needs to adjust the workstations accordingly	Through Gemba & Process Analysis	Confirmed
Poor Line Balancing	Because the hypothetical targets are being provided to each workstation based on the experience of line supervisor & no actual formulation is available for line balancing	Develop line balancing system & check Current Status	Confirmed
Lack of Multi Skilled Workers	Due to permanent allocation of similar operation workers, multiple operational skills cannot be developed	Daily Performa Status	Confirmed
Rework	Due to excessive rework, more chances of losses	Quality check Sheet	Not confirmed

Figure 35 shows the verification results

- Frequent Changeover

The cause was verified through process analysis. The line under observation was using “U” shape layout. As the order quantities are small, so every time article changes in line the work stations needs to be adjusted accordingly. The order quantities varies from 80 Pairs to 600 Pairs. And the analysis made in previous shows that whenever an article changes line undergoes a excessive production loss.

- Poor Line Balancing

There isn’t any concept of line balancing. Everything is being done on the experience of line supervisor. Line’s supervisor is allocating the targets to workstations on the hypothetical basis therefore some stations have excessive WIP and some workstations are completely vacant. The current conditions of line balancing are verified after designing formulated line balancing system.

- Lack of Multi skilled Workers

Workers in the line under observation are not multiskilled. Workers are used for some particular operations either easy or difficult. Therefore workers are handy about what they have been doing since their joining. That is why replacement for any critical operation is not available. The cause was verified from the daily Performa that workers fill for their wages purpose.

- Rework

Only cause that was not verified using this theory is Rework. When quality check sheet was observed the rework it narrated that rework for the line under observation is not that high so that it make a considerable difference in production. Because the inline quality for closing lines is very strict. So we rules out this option that the loss might be because of the rework.

Now that all the causes have been verified we document in tabular form the major causes and the possible solutions to the problems that will be further used in the improvement phase. These solutions were obtained from the team input.

S. No	Potential Root Cause	Possible Solution
1	Frequent change in layout due to high changeover because of small order quantities	Break the line into 2 cells & change the layout from "U" shape to "Zig zag"
2	Line balancing is being done based on the hypothetical targets & line supervisor's experience	Prepare a formulated line balancing structure that is easy to use by production team
3	Due to permanent allocation of similar operation workers, multiple operational skills cannot be developed	Training school should be created so that workers can be trained on multiple operations

Table 1 Cause & Possible Solution

4.4.4 Formulation for Line Balancing

4.4.4.1 Takt Time

Takt time is a time that is used to help match the rate of production in a pacemaker process to the rate of target. This can be formulated as below.

$$\textbf{Takt Time} = \frac{\textbf{Total SAM per pair}}{\textbf{Planned Manpower}}$$

Takt time can be defined as the rate at which target for the complete line can be met. The products should be produced at least equal to takt time to achieve the target. Takt time works better when target is steady and clearly known; but if the target varies on the daily basis then it is difficult to calculate the takt time as well as balance the production facility according to varying takt time.

Now the project team has formulated line balancing format based on the article takt time. Now the team will consider an article running in the closing line & check the existing structure by using formulated line balancing format to study the production loss.

Formulation for Line Balancing Experiment on Article # Mocc-1

Now team will calculate takt time for the article # Mocc-1

SAM of the article = 37.35 min.

Planned Manpower = 45 Person

Now calculating takt time according to formula.

$$\textbf{Takt Time} = \frac{\textbf{Standard Allowed Minutes}}{\textbf{Manpower}}$$

SAM of Article = <u>37.35 min.</u>

No. of Person = <u>45 person</u>

<u>Takt time</u> = <u>0.83 min.</u>

Now according to takt time each work station needs to produce output of

$$\text{Target/Hour} = \frac{60}{.83} = \textbf{72 pairs / Hour}$$

Now due to different capacity of each operation & worker skill level, project team has decided a range of 20% at takt time to balance all the operations. Therefore now the range of target according to takt time has become,

U.C.L = 72 pairs X 1.20 = **<u>90 Pairs</u>**

L.C.L = 72 pairs X .80 = **<u>60 Pairs</u>**

Takt Time = <u>72 Pairs</u>

4.4.5 Line Balancing Experiment on Article MOCC - 1

LAY OUT

STYLE NO : **MOCC -1** | **S.M.V :** **37.35** | **LINE NO :** **L-1** | **M/PWR:** **45**

Stn	M/C	Operations	SMV	Total / Target	M/C	Operations	SMV	Total / Target	Stn
45	**Man**	59 Pairing & packing 60 Re-Counting	0.26 0.30	0.56 **107**					46
43	**MAN**	57 Thread burning 58 Cleaning (Regular) Mocassions, Strobbled,	0.46 0.78	1.24 **48**	**Man**	58 Cleaning (Regular) Mocassions, Strobbled, 57 Thread burning	0.78 0.46	1.24 **48**	44
41	**Man**	53 Trim counter lining 54 Trim Upper Lining 55 Trim apron lining	0.74 0.60 0.42	1.76 **34**	**Man**	56 Thread triming + notch triming	0.66	0.66 **91**	42
39	**Man**	53 Trim counter lining 54 Trim Upper Lining 55 Trim apron lining	0.74 0.60 0.42	1.76 **34**	**Man**	53 Trim counter lining 54 Trim Upper Lining 55 Trim apron lining	0.74 0.6 0.42	1.76 **34**	40
37	**MAN**	51 Repunch Apparon 52 Repunch Vamp	0.92 0.92	1.84 **33**	**MAN**	51 Repunch Apparon 52 Repunch Vamp	0.92 0.92	1.84 **33**	38
35	**SNL**	49 Top stitch collar bottom edge	0.88	0.88 **68**	**SNL**	50 Close Elastic End	1.32	1.32 **45**	36
33	**Man**	47 Cement Upper & collar for folding (Whole	0.92	0.92 **65**	**Man**	48 Fold collar	1.22	1.22 **49**	34
31	**SNL**	43 Ts Heel Grip	0.50	0.5 **120**	**SNL**	46 Join collar strap with upper	1.02	1.02 **59**	32
29	**SNL**	39 Top stitch tongue edge 25 Top Stitch Collar Join	0.56 0.34	0.9 **67**	**Man**	40 Cement heel grip 41 Cement Vamp Lining Edge 42 Fit heel grip to back counter (moccasin)	0.26 0.44 0.52	1.22 **49**	30
27	**Man**	37 Spray apron/Lining 44 Spray Vamp/vamp lining	0.44 0.68	1.12 **54**	**Man**	38 Fit Lining to apron 45 Fit Lining to vamp (moccasin)	0.52 1.22	1.74 **34**	28
25	**Man**	33 Cement Elastic (Small) 34 Cement Appron / vamp edge for fitting	0.56 0.68	1.24 **48**	**Man**	35 Fit Elastic Edge 36 Fit Elastic Edge	0.68 0.68	1.36 **44**	26
23	**Man**	29 Trim Lacing+Paste	0.56	0.56 **107**	**Man**	30 Cut ribbon 31 Cement Ribbon 32 Fit Ribbon	0.28 0.44 0.32	1.04 **58**	24
21	**Snap**	27 Eyeletting Collar piece (8 holes)	0.78	0.78 **77**	**Man**	28 Collar lacing (8 holes) 25 Top Stitch Collar Join	1.34 0.34	1.68 **36**	22
19	**MAN**	26 Repunch	0.48	0.48 **125**	**Snap**	27 Eyeletting Collar piece (8 holes)	0.78	0.78 **77**	20
17	**Man**	23 Edge Cementing (Small) 24 Edge Fitting (Small)	0.34 0.44	0.78 **77**	**SNL**	25 Top Stitch Collar Join	0.34	0.34 **176**	18

Station	Type	No.	Operation	SMV	Total / Pairs
15	**DNL**	22	Top stitch counter 2 sided	1.56	1.56 **38**
13	**Man**	16 17 18	Cement stiffner Cement counter For Stiffener Fit Fit Stiffner with back counter	0.22 0.26 0.44	0.92 **65**
11	**Man**	12 13 14 15	Fit Tape to Apron zig zag seam Hammering Appron ZZ seam Fit Tape to Vamp zig zag seam Hammering Vamp ZZ seam	0.26 0.22 0.44 0.48	1.4 **43**
9	**ZZ**	9 10 11	ZZ stifner seam + thread triming ZZ Apron Lining ZZ Vamp Lining	0.30 0.32 0.64	1.26 **48**
7	**Press**	6	Press Fusing	1.12	1.12 **54**
5	**PRESS**	5	Rotary Press 1 Cycle	0.51	0.51 **118**
3	**Man**	3	Cement for backer fitting(spot)	0.66	0.66 **91**
1	**Press**	1 2	Fit & Press fusing on Apparon Edge (WJ-1 Fit & Press fusing on Vamp Edge (WJ-150	1.10 1.10	2.2 **27**

Type	No.	Operation	SMV	Total / Pairs	Station
DNL	22	Top stitch counter 2 sided	1.56	1.56 **38**	16
Man	16 17 18	Cement stiffner Cement counter For Stiffener Fit Fit Stiffner with back counter	0.22 0.26 0.44	0.92 **65**	14
Man	12 13 14 15	Fit Tape to Apron zig zag seam Hammering Appron ZZ seam Fit Tape to Vamp zig zag seam Hammering Vamp ZZ seam	0.26 0.22 0.44 0.48	1.4 **43**	12
ZZ	9 10 11	ZZ stifner seam + thread triming ZZ Apron Lining ZZ Vamp Lining	0.3 0.32 0.64	1.26 **48**	10
SNL	7 8	Join back counter seam Fit tape to counter seam	0.5 0.26	0.76 **79**	8
Press	6	Press Fusing	1.12	1.12 **54**	6
MAN	4	Allign Backer (1 Component)	0.96	0.96 **63**	4
Press	1 2	Fit & Press fusing on Apparon Edge (WJ-1 Fit & Press fusing on Vamp Edge (WJ-150	1.1 1.1	2.2 **27**	2

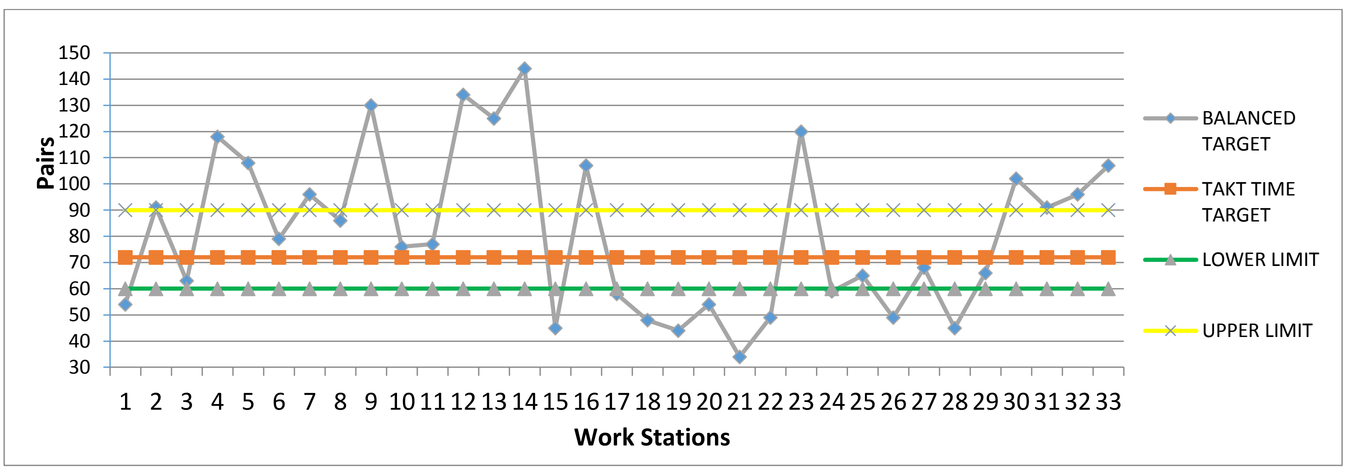


Figure 36 Current Ling balancing Condition

Now through this line balancing format project team has found that according to the current situation and process of line balancing (i.e. Line's Forman experience) almost 80% of the workstations are not balanced as per takt time to achieve the target.

4.4.6 “WHY´S” Tool for Root Cause Analysis

5Why’s tool is an approach for root cause analysis. It is used when asking the major cause 5 times the question why? To get to the grass root of the problem. It is used in the project to connect the causes to the root cause and create an action plan improve the conditions. This technique is a Japanese method to determine the roots cause. It is not possible to obtain the roots cause of the problem without asking 5 times “why”, so it is important for the team to be able to know when to stop asking this question.

5 WHY's ROOT CAUSE ANALYSIS CHART					
Causes	**Why 1?**	**Why 2?**	**Why 3?**	**Why 4?**	**Why 5?**
Poor Line Balancing	There isn't any structure of line balancing	Because operational targets were not defined	Because Management was working on the basis of hypothetical targets	Because operational SAM (Standerd Allowed Minutes) were not available	Because there isn't any structured SAM data bank or OBD available
High Changeover Effect	Plan quantity of each article is small	Layout needs to be changed according to each article	Each article has different flow	Each article is highly customized	Closing line is using U shape layout

Figure 37 5 WHY Root Cause Analysis

The following tables shows how the 5W’s tool was used to get to the roots cause of the major causes found in the Measure and Analyze phases of the methodology used in the project to connect the causes to the root cause and create an action plan that will be described in the Improve phase of the project.

4.4.7 FAILURE MODE & EFFECT ANALYSIS

Failure Mode and Effects Analysis (FMEA) is a technique intended to identify and understand possible failure modes and their causes and the effects of failure on the system, for a given process. FMEA measure the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action. It identify and carry out corrective actions to address the most serious concerns. It is done by a cross-functional team of subject matter experts that systematically examines manufacturing processes. Determine and corrects weaknesses in the process to get the desired results. FMEA is the leader to the improvement of a complete set of actions that will decrease risk associated with the manufacturing process to an acceptable level.

Now the project team will be using FMEA tool to find out the cause of less productivity & the risk associated to that.

FAILURE MODE & EFFECT ANALYSIS (FMEA) WORKSHEET

Closing Line Process Steps	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Cause of Failure	Occurenece	Current Process Control (Detection)	Detection	RPN
Line Balancing	Target Not Achieved from Workstation	Excessive or Less Operation/Station	4	Unjustified Operational Allocation	3	Production Foreman is responsible for operation adjustment	4	48
	Multiple Operations can't be performed	Excessice WIP	3	Unskilled worker	3	Skilled workers are provided with more operations	4	36
	Different Output Rate From Different Operations	Excessive Worker Idleness	5	Hypothetical Operational Targets	5	Production Managers are responsible for defining targets	5	125
	Operation Allocation	Excessive NPT (Non-Productive Time)	4	Unavailability of Formulation for Line Balancing	5	Line Foreman's Experience is used for line balancing	5	100
Layout Planning	Shorter Run Articles	Low Productivity	5	Frequent Changeover	4	Line is feeded with longer run articles	4	80
	Excessive Machine Downtime	Excessive NPT (Non-Productive Time)	4	Changing Machine Settings	3	Machine replacement	4	48

Note : Rating scale is used from 1 to 5

Figure 38 FMEA Work Sheet

Now the project team have prepared FMEA worksheet for closing line so as to find out the potential failure modes & causes behind them. From the above failure mode & effect analysis (FMEA) worksheet for closing line project team have found out that causes having maximum Risk Priority Number (RPN) are 1. Hypothetical Operational targets 2. Unavailability of formulation of line balancing 3. Frequent changeover.

Now this FMEA worksheet has more précised the focus of project team over the causes behind the low productivity of the closing line. Now to improve the productivity of the closing line project team will be looking forward to counter & improve the cause with maximum RPN.

4.4.8 FOCUSED PROBLEM STATEMENT

4.4.8.1 Pareto Chart

Pareto chart is a graphical tool to that assists in breaking a big problem down into its portions and identifies which portions are the most important for the problem to be solved. It is used in the measure phase of DMAIC to focus at the problem once the data collection and data verification has been done. It is extremely useful in understanding the patterns of occurrence of problems and find out the relative impact of the parts of the problem and it clarifies the areas where to focus our efforts on if we want to obtain the targets of our DMAIC initiative.

Now team will be applying Pareto chart to focus at the problem which is becoming the main cause of productivity loss in closing line.

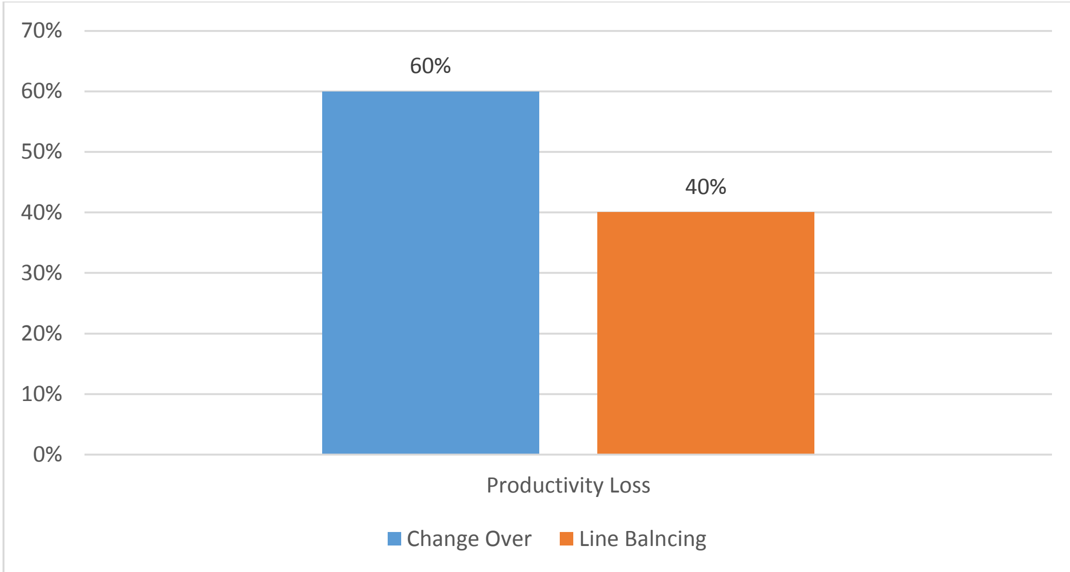


Figure 39 Focused Problem Analysis

Pareto chart explains the situation that the main problems causing productivity loss in a closing lines are 1- Changeover & 2- Line balancing.

The final statement conscripted using Pareto chart is given “From above data Analysis, it is clear that we will be focusing at changeover & line balancing issues of the closing line. We have to increase the productivity of the closing line by 10-15% to achieve the project team & management’s desired line efficiency.

4.5 IMPROVE PHASE

The improvement phase has the basic goal to identify, validate and implement the improvements or changes to overcome the potential rework and losses. When we reach the improve phase we have two methods or options to implement the improvements one is the data way and the other is the process way.

The data way is taken when after analyze phase the solutions are not obvious in this option the risks of implementation are high and we use design of experiments and the approach is quantitative. This method is used when the solutions are not obvious after the analysis of data the factors have been identified but solutions for improving them are not clear yet or the risks in implementation are extremely high. In such cases we use the design of experiment to quantify and identify the solutions.

The second way is the process way this method is taken when we have clear identification of the issues and from this identification it is clear that what the solutions should be and the risks of implementing the solutions are low. The tools used are feedback from the teams and process mapping are used. This is a qualitative technique and the usual solutions are revised process, cutting out waste and NVA (Non value added process steps), and implementation of performance Measures.

4.5.1 Changeover Time Comparison

Changeover time is very important in a manufacturing facility where the product changes frequently. Excessive changeover time increase waste, effect productivity & become the cause of low efficiency.

Shorter changeover time reduces waste of

- Over production
- Inventory
- Time
- Labor
- Defects

Shorter changeover time allow faster production cycle, faster cycles reduce inventory, faster cycles increase production flexibility & minimize the production lead time.

After analysis & research project team have found that high changeover time is one of the main issues behind the low productivity of the closing line. So project team will calculate the changeover time for Moccasin to Long Boot, Moccasin to Moccasin & Long Boot to Long Boot to analyze the lost time due to changeover.

LOST MINUTES ANALYSIS WHILE CHANGEOVER TIME ANALYSIS								
Changeover	ANALYSIS-1 (Min)	ANALYSIS-2 (Min)	ANALYSIS-3 (Min)	ANALYSIS-4 (Min)	ANALYSIS-5 (Min)	AVERAGE (Min)	Available Time at 45 Worker	%age of Lost Min. on Changeover
Long Boot To Long Boot	12110	13890	13310	12690	13360	13072	25650	51%
Moccasin To Booty	14474	15101	15272	14327	13790	14593	25650	57%
Moccasin To Moccasin	13210	10106	12047	11232	12701	11859	25650	46%

Figure 40 Change over Time Analysis

From the analysis project team has found that the changeover time between moccasins to long boot articles is 57% of the total available time that is very high as compare to change over time between moccasin to moccasin & long boot to long boot articles. Due to operational complexity & component handling of long boot it is difficult for closing line workers to frequently adjust from moccasin to long boots. Because as per previous analysis we have seen that number of operations in long boot is very high as compare to moccasin so the number of operations per station increase as the article changes from moccasin to long boot& because most of the closing line workers are not multi skilled so it is not possible for them to frequently adjust between the changeover of two different form of shoe.

4.5.2 Prioritization Tool for Solution

The first step is to prioritize the solutions already established in the last phase in this step the solutions are divided into deliverable and concrete form and ready for implementation before they are categorized using the prioritization tool already discussed in the analyze phase but this time in more detail. The figure bellow highlights the solutions we will be implementing in this phase.

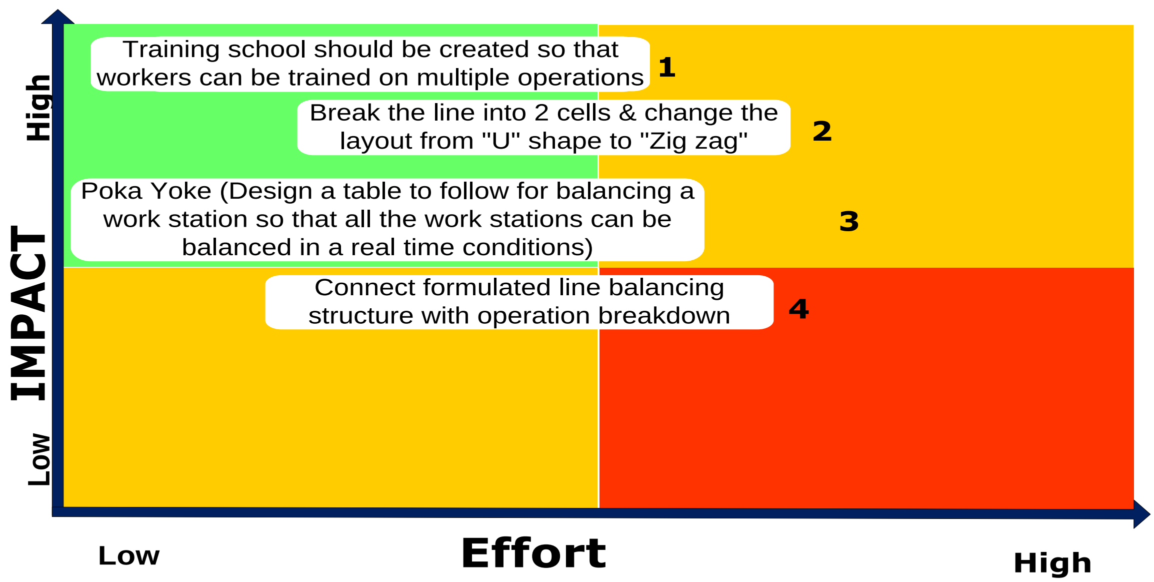
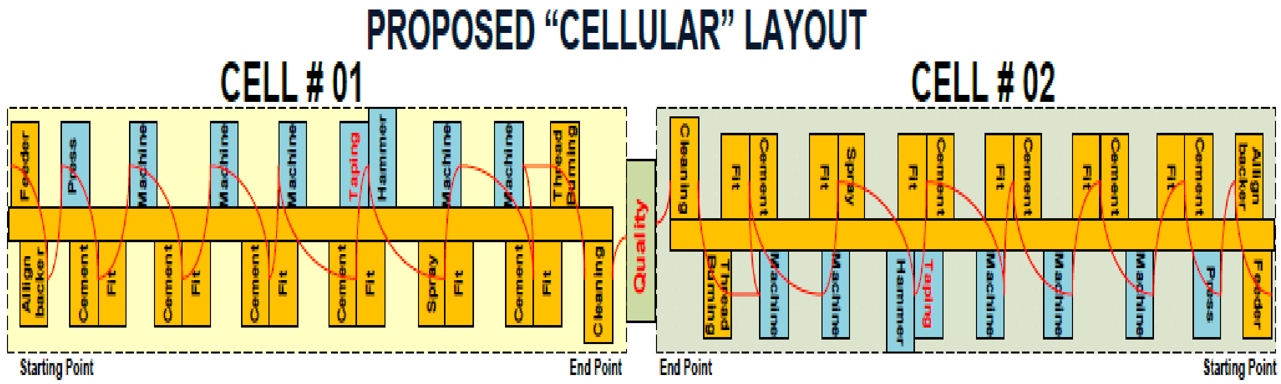


Figure 41Prioritized matrix of proposed solutions

4.5.3 Product Based Cellular Manufacturing concept for Changeover Time Reduction

Cellular manufacturing can be considered as a concept of management, based on the theory that "similar things should be done similarly". The theory of cellular manufacturing is to divide the manufacturing facility into groups or *cells*. Each of these cells is dedicated to a specified product family. Cellular manufacturing can be seen as a role model to attain the advantages off low line systems in environments previously ruled by job shop layouts. The idea is to formgroups and to aim at a product-type layout within each group. New parts are designed to be compatible with the processes and layout of an existing part family. This way, production experience is quickly obtained, and standard process plans can be developed for this restricted part set.

Now so as to control the productivity loss due to excessive changeover project team has decided to make product based cells for long boots & moccasin. These cells will be dealing with moccasin & long boot article respectively & will be based on fixed layout. Workers are cross-trained on all operations within the group and follow the job from Start to finish. It will lead to higher job satisfaction and higher efficiency.



4.5.4 POKA YOKE

The first solution which will be discussed and implemented is to error proof the design for line balancing criteria using Poke yoke. Some of the chances of errors that were considered in this step are

- Non Value Added Activities: These are the activities that increased the throughput time & cause bottle necks in balancing the line according to the takt time, so these activities must be removed.
- Work Distribution: Operations must be balanced & distributes such that every worker must get work according to its work station.
- Update Calculations: Update the calculations after removing the non-value added activities, so that line can be balanced according to updated takt time.

The process of line balancing is formatted in order to do mistake-proofing& help to minimize or eliminate Mistakes. This process of line balancing will be used to balance each workstation of closing line as per requirement & capacity.

The major problem in closing line is line balancing so the project team prepared a line balancing process so that each & every station of the line can be balanced according to its capacity.

Below mention is the process flow of formulations to balance the line.

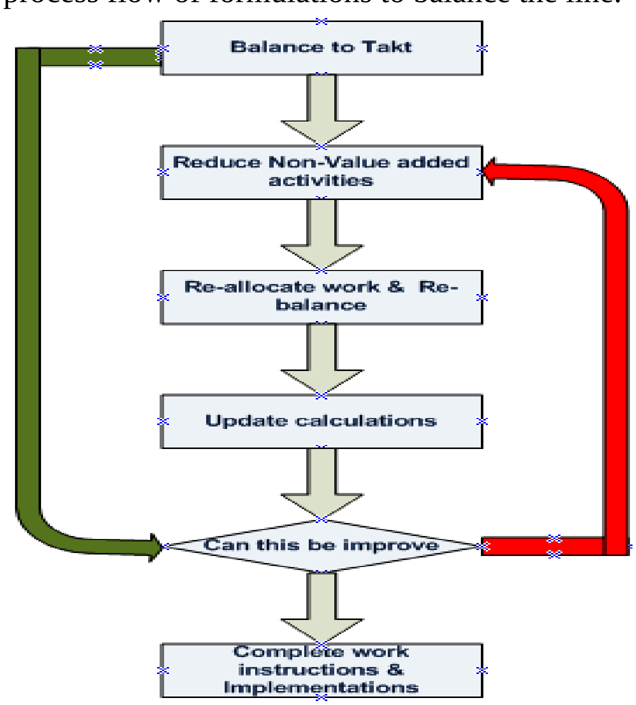


Figure 42 POKA YOKE for Line Balancing

4.5.5 Formulation for Line Balancing

Takt Time

Takt time is a time that is used to help match the rate of production in a pacemaker process to the rate of target. This can be formulated as below.

$$\text{Takt Time} = \frac{\text{Total SAM per pair}}{\text{Planned Manpower}}$$

Takt time can be defined as the rate at which target for the complete line can be met. The products should be produced at least equal to takt time to achieve the target. Takt time works better when target is steady and clearly known; but if the target varies on the daily basis then it is difficult to calculate the takt time as well asbalance the production facility according to varying takt time.

Now the project team has formulated line balancing format based on the article takt time. Now the team will consider an article running in the closing line & check the existing structure by using formulated line balancing format to study the production loss.

4.5.5.1 Formulation for Line Balancing Experiment on Moccasin Article # 1

Now team will calculate takt time for the article # 1

SAM of the article = 33.49 min.

Planned Manpower = 35 Person

Now calculating takt time according to formula.

$$\text{Takt Time} = \frac{\text{Standard Allowed Minutes}}{\text{Manpower}}$$

SAM of Article = **<u>33.49 min.</u>**

No. of Person = **<u>20 person</u>**

<u>Takt time</u> = **<u>1.67 min.</u>**

Now according to takt time each work station needs to produce output of

$$\text{Target/Hour} = \frac{60}{1.67} = \textbf{36 pairs / Hour}$$

Now due to different capacity of each operation & worker skill level, project team has decided a range of 20% at takt time to balance all the operations. Therefore now the range of target according to takt time has become,

U.C.L = 36 pairs X 1.20 = <u>45 Pairs</u>

L.C.L = 36 pairs X .80 = <u>30 Pairs</u>

Takt Time = <u>36 Pairs</u>

4.5.5.2 Line balancing of Moccasin 1

LAY OUT

STYLE NO : MOCC-1	S.M.V : 33.49	LINE NO :	M/PWR: 20

Stn	Type	Operations	SMV	Total / Target	Type	Operations	SMV	Total / Target	Stn
21	Trim	48 Trim Upper Lining 49 Trim apron lining 50 Cleaning (Regular) Mocassions, Strobbled,	0.60 0.42 0.78	1.8 33					22
19	Man	41 Cement Upper & collar for folding (Whole 42 Fold collar	0.92 1.22	2.14 28	MAN	45 Repunch Apparon 46 Repunch Vamp	0.92 0.92	1.84 33	20
17	SNL	40 Join collar strap with upper 43 Top stitch collar bottom edge 44 Close Elastic End	1.02 0.88 1.32	3.22 19	SNL	40 Join collar strap with upper 43 Top stitch collar bottom edge 44 Close Elastic End	1.02 0.88 1.32	3.22 19	18
15	Man	34 Spray apron/Lining 38 Spray Vamp/vamp lining	0.44 0.68	1.12 54	Man	39 Fit Lining to vamp (moccasin) 33 Fit Elastic Edge	1.22 0.68	1.9 32	16
13	Man	30 Cement Elastic (Small) 31 Cement Appron / vamp edge for fitting 32 Fit Elastic Edge 33 Fit Elastic Edge	0.56 0.68 0.68 0.68	2.6 23	Man	30 Cement Elastic (Small) 31 Cement Appron / vamp edge for fitting 32 Fit Elastic Edge 33 Fit Elastic Edge	0.56 0.68 0.68 0.68	2.6 23	14
11	MAN	23 Repunch 24 Eyeletting Collar piece (8 holes) 25 Collar lacing (8 holes) 26 Trim Lacing+Paste	0.48 0.78 1.34 0.56	3.16 19	MAN	23 Repunch 24 Eyeletting Collar piece (8 holes) 25 Collar lacing (8 holes) 26 Trim Lacing+Paste	0.48 0.78 1.34 0.56	3.16 19	12
9	DNL	19 Top stitch counter 2 sided 22 Top Stitch Collar Join	1.56 0.34	1.9 32	Man	20 Edge Cementing (Small) 21 Edge Fitting (Small) 27 Cut ribbon 28 Cement Ribbon	0.34 0.44 0.28 0.44	1.5 40	10
7	Man	13 Cement stiffner 14 Cement counter For Stiffener Fit 16 Cement counter edge to fit with upper 17 Cement upper back for back counter fitting	0.22 0.26 0.38 0.44	1.3 46	Man	15 Fit Stiffner with back counter 18 Fit counter to upper (moccasin) 29 Fit Ribbon	0.44 0.7 0.32	1.46 41	8
5	SNL	6 Join back counter seam 36 Top stitch tongue edge 37 Ts Heel Grip	0.50 0.56 0.50	1.56 38	ZZ	8 ZZ stifner seam + thread triming 9 ZZ Apron Lining 10 ZZ Vamp Lining	0.3 0.32 1	1.62 37	6
3	Man	3 Cement for backer fitting(spot) 4 Rotary Press 1 Cycle	0.90 0.51	1.41 43	M/C	11 Fit Tape to Apron zig zag seam 12 Fit Tape to Vamp zig zag seam 7 Fit tape to counter seam 47 Trim counter lining	0.3 0.3 0.26 0.74	1.6 38	4
1	Press	1 Fit & Press fusing on Apparon Edge (WJ-1 2 Fit & Press fusing on Vamp Edge (WJ-150 4 Rotary Press 1 Cycle	1.20 1.20 0.51	2.91 21	Press	1 Fit & Press fusing on Apparon Edge (WJ-1 2 Fit & Press fusing on Vamp Edge (WJ-150 4 Rotary Press 1 Cycle	1.2 1.2 0.51	2.91 21	2

4.5.5.3 GRAPHICAL REPRESENTATION OF MOCCASIN # 1 LINE BALANCING

BALANCED CLOSING LINE OPERATION'S ANALYSIS FOR MOCCASIN

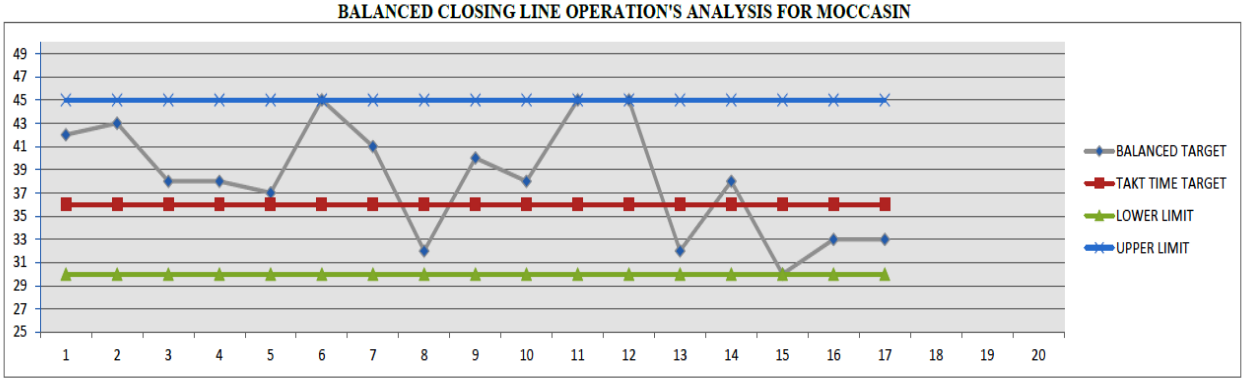


Figure 43 GRAPHICAL REPRESENTATION OF MOCCASIN # 1 LINE BALANCING

4.5.5.4 Formulation for Line Balancing Experiment on Moccasin Article # 2

Now team will calculate takt time for the article # 2

SAM of the article = 31.24 min.

Planned Manpower = 20 Person

Now calculating takt time according to formula.

$$\textbf{Takt Time} = \frac{\textbf{Standard Allowed Minutes}}{\textbf{Manpower}}$$

SAM of Article = **31.24 min.**

No. of Person = **20 person**

Takt time = **1.56 min.**

Now according to takt time each work station needs to produce output of

$$\text{Target/Hour} = \frac{60}{1.56} = \textbf{38 pairs / Hour}$$

Now due to different capacity of each operation & worker skill level, project team has decided a range of 20% at takt time to balance all the operations. Therefore now the range of target according to takt time has become,

U.C.L = **38 pairs X 1.20** = **48 Pairs**

L.C.L = **38 pairs X .80** = **32 Pairs**

Takt Time = **38 Pairs**

4.5.5.5 Line balancing of Moccasin 2

LAY OUT

STYLE NO : MOCC-2 **S.M.V : 31.24** **LINE NO :** **M/PWR: 20**

Stn	Type	Operations	SMV	Total / Target	Type	Operations	SMV	Total / Target	Stn
19	**MAN**	42 Repunch Apparon 43 Repunch Vamp 46 Repunch Holes For hand Stitching 47 Edge Clr	0.66 0.66 1.04 0.20	2.56 **23**	**Trim**	44 Trim apron lining 45 Trim Upper Lining 48 Cleaning (Regular) Mocassions, Strobbled	0.42 0.6 0.78	1.8 **33**	20
17	**Man**	38 Cement Upper & collar for folding (Whole 39 Hammering collar seam 40 Fold collar	0.92 0.72 1.22	2.86 **21**	**MAN**	42 Repunch Apparon 43 Repunch Vamp 46 Repunch Holes For hand Stitching 47 Edge Clr	0.66 0.66 1.04 0.2	2.56 **23**	18
15	**SNL**	37 Join collar strap with upper 41 Top stitch collar bottom edge	1.02 0.88	1.9 **32**	**Man**	38 Cement Upper & collar for folding (Whole 39 Hammering collar seam 40 Fold collar	0.92 0.72 1.22	2.86 **21**	16
13	**Man**	26 Cement Elastic (Small) 27 Cement Vamp Edges 28 Fit Elastic Edge	0.56 0.68 0.68	1.92 **31**	**Man**	30 Cut ribbon 31 Cement Ribbon 32 Cement Elastic (Small) 33 Fit Ribbon	0.28 0.44 0.56 0.32	1.6 **38**	14
11	**SNL**	23 Ts Heel Grip 29 Top Stitch Straight	0.50 0.72	1.22 **49**	**PRESS**	24 Press Eyeletstay 25 Elastic Hmmaering	1.12 0.36	1.48 **41**	12
9	**Man**	16 Spray apron/Lining 17 Fit Lining to apron 34 Spray Vamp/vamp lining 35 Fit Lining with Upper (Moccasin)	0.44 0.52 0.68 1.80	3.44 **17**	**Man**	20 Cement stiffner 21 Cement counter For Stiffener Fit 22 Fit stiffner to back counter (Moccasin) 36 Press Vamp lining	0.22 0.26 0.44 0.7	1.62 **37**	10
7	**SNL**	12 Top Stitch Vamp Side 14 Join vamp back seam 19 Top stitch tongue edge Curvy	0.44 0.44 0.80	1.68 **36**	**Man**	16 Spray apron/Lining 17 Fit Lining to apron 34 Spray Vamp/vamp lining 35 Fit Lining with Upper (Moccasin)	0.44 0.52 0.68 1.8	3.44 **17**	8
5	**Man**	6 Cement Elastic (Small) 7 Cement Apparon Edge For Fitting 8 Fit Elastic Edge	0.56 0.34 0.68	1.58 **38**	**Man**	9 Cement Vamp Edges 10 Edge Cementing (Small) 11 Edge Fitting (Small) 15 Hammering Seam	0.34 0.34 0.44 0.28	1.4 **43**	6
3	**Man**	3 Cement & Allign Backer 4 Allign Backer (1 Component)	0.66 0.96	1.62 **37**	**PRESS**	5 Rotary Press 1 Cycle 18 Press Apparon lining 36 Press Vamp lining	1.02 0.36 0.7	2.08 **29**	4
1	**Press**	1 Fit & Press fusing on Apparon Edge (WJ-1 2 Fit & Press fusing on Vamp Edge (WJ-15(13 Fit & Fusing To Collar strap	1.20 1.20 0.78	3.18 **19**	**Press**	1 Fit & Press fusing on Apparon Edge (WJ-1 2 Fit & Press fusing on Vamp Edge (WJ-15(13 Fit & Fusing To Collar strap	1.2 1.2 0.78	3.18 **19**	2

4.5.5.6 GRAPHICAL REPRESENTATION OF MOCCASIN # 2 LINE BALANCING

BALANCED CLOSING LINE OPERATION'S ANALYSIS FOR MOCCASIN

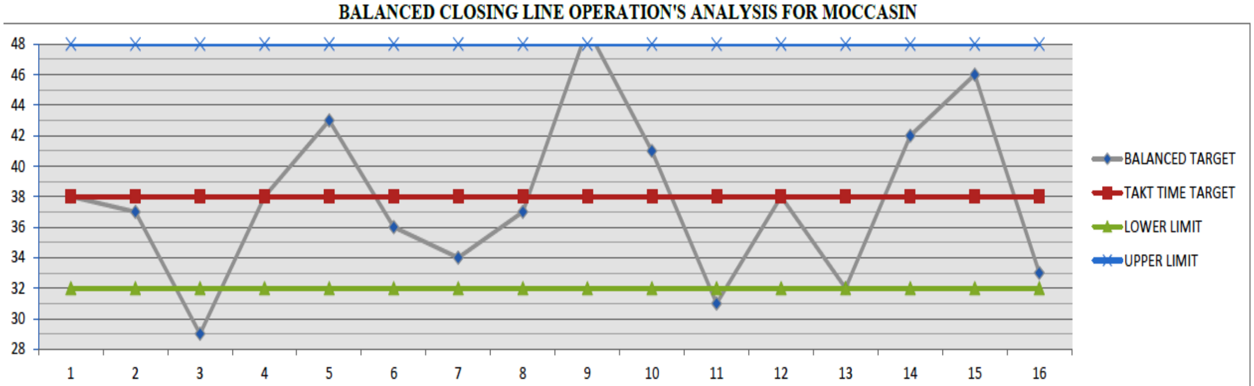


Figure 44 GRAPHICAL REPRESENTATION OF MOCCASIN # 2 LINE BALANCING

4.5.5.7 Formulation for Line Balancing Experiment on Long Boot Article # 1

Now team will calculate takt time for the article # 1

SAM of the article = 42.56 min.

Planned Manpower = 40 Person

Now calculating takt time according to formula.

Takt Time	**=**	**<u>Standard Allowed Minutes</u>**
		Manpower

SAM of Article	**=**	**<u>42.56 min.</u>**
No. of Person	**=**	**<u>20 person</u>**
<u>Takt time</u>	**=**	**<u>2.13 min.</u>**

Now according to takt time each work station needs to produce output of

$$\text{Target/Hour} = \frac{60}{2.13} = \mathbf{28\ pairs\ /\ Hour}$$

U.C.L =	**28 pairs X 1.20**	**= <u>35 Pairs</u>**
L.C.L =	**28 pairs X .80**	**= <u>23 Pairs</u>**
	Takt Time	**= <u>28 Pairs</u>**

4.5.5.8 Line balancing of Long Boot 1

LAY OUT

STYLE NO : LB-1	S.M.V : 42.56	LINE NO :	M/PWR: 20

Stn	M/C	Operation	SMV	Total / Target	M/C	Operation	SMV	Total / Target	Stn
21	Man	67 Cleaning Booty (Winter) 68 Edge Clr	1.50 0.60	2.1 29					22
19	Man	58 Cement Stiffner (Boot) 59 Cement counter For Stiffener Fit 60 Fit stiffner to back counter (Moccasin) 61 Cement Stiffner (Boot)	0.26 0.26 0.44 0.26	1.22 49	MAN	64 Cut Elastic Lining(BOOTY) 65 Trim Fur Lining (Medium) 66 Collar Lining Triming	0.24 1.36 0.6	2.2 27	20
17	Man	52 Cement Upper (Full) Medium 53 Cement Lining (Full) Medium	1.18 1.30	2.48 24	SNL	50 Top Stitch Zip Cover Piece (Mid) 51 Top Stitch Heel Grip 56 Top Stitch Collar Edge Including Elastic (57 Zip Reinforcment Stitch	0.56 0.5 1.2 0.3	2.56 23	18
15	Man	44 Cement Collr Pu Lining 45 Cement Fur Lining 46 Fit Pu Lining With Fur Lining 54 Fit Lining With Upper (Medium)	0.40 0.38 0.44 2.84	4.06 15	Man	44 Cement Collr Pu Lining 45 Cement Fur Lining 46 Fit Pu Lining With Fur Lining 54 Fit Lining With Upper (Medium)	0.4 0.38 0.44 2.84	4.06 15	16
13	ZZ	35 Zig Zag Quarter Lining Front Seam(M) 36 Join Qrter Lining With Vamp Lining 37 Zig Zag Lining Lock 38 ZZ stifner seam + thread triming	0.66 0.56 0.40 0.30	1.92 31	SNL	40 Join Quarter Lining Bk Seam (Medium) 41 Cut 42 Cement Label 43 Fold & Fit Label	0.8 0.3 0.27 0.39	1.76 34	14
11	Man	31 Fit Zip (Medium) 32 Mark Zip For Trim 33 Trim Zip 55 Top Stitch Zip Edge (Medium)	1.08 0.18 0.14 1.14	2.54 24	SNL	34 Top Stitch Zip Edge (Medium) 47 Top Stitch Collar Pu Lining 50 Top Stitch Zip Cover Piece (Mid)	1.14 0.52 0.56	2.22 27	12
9	Man	22 Cement Vamp Edge for fitting 23 Cement Upper Edge For Vamp Fit 24 Fit Vamp To Upper (BooTop Stitch)	0.44 0.44 1.22	2.1 29	Man	27 Edge Cementing (Small) 28 Fold Zip 29 Cement Zip (Medium) 30 Cement Upper Fr Zip Fit (Medium)	0.34 0.36 0.5 0.6	1.8 33	10
7	SNL	16 Join back counter seam 63 Toe Tacking 21 Top Stitch Back Counter Edge 26 Top Stitch Vamp Edge Rgr	0.50 0.44 0.66 0.70	2.3 26	Man	18 Edge Cementing (Small) 19 Edge Cementing (Small) 20 Edge Fitting (Small)	0.68 0.68 0.88	2.24 27	8
5	Man	11 Cement Elastic (Small) 12 Edge Cementing (Small) 13 Fit Elastic Edge 15 Fold Collar Edge	0.28 0.34 0.34 0.92	1.88 32	Man	14 Cement Collar Edge For Folding 48 Cement Zip Cover Medium 49 Fit Zip Cover Medium	0.62 0.68 0.44	1.74 34	6
3	PRESS	4 Toe Puff 25 Fit tape to vamp sides 39 Taping Vamp Zig Zag Seam 62 Fit Heel Grip With Stiffener After Re Cem	0.56 0.54 0.52 0.24	1.86 32	SNL	5 Join Qrter Frnt/ Bk Seam (Medium) 6 Join Qrter Frnt/ Bk Seam (Medium) 7 Taping Quarter Front/ Bk Seam 8 Taping Quarter Front/ Bk Seam	0.66 0.66 0.3 0.3	1.92 31	4
1	Man	1 Cement for backer fitting(spot) 2 Rotary Press 1 Cycle	1.32 1.02	2.34 26	MAN	3 Fit Tape To Toe 10 Elastic Hmmaering 17 Fit tape to counter seam 9 Fit Fusing On Collar (Single Pc) BootTop	0.36 0.18 0.26 1.08	1.88 32	2

4.5.5.9 GRAPHICAL REPRESENTATION OF LONG BOOT # 1 LINE BALANCING

BALANCED CLOSING LINE OPERATION'S ANALYSIS FOR LONG BOOT

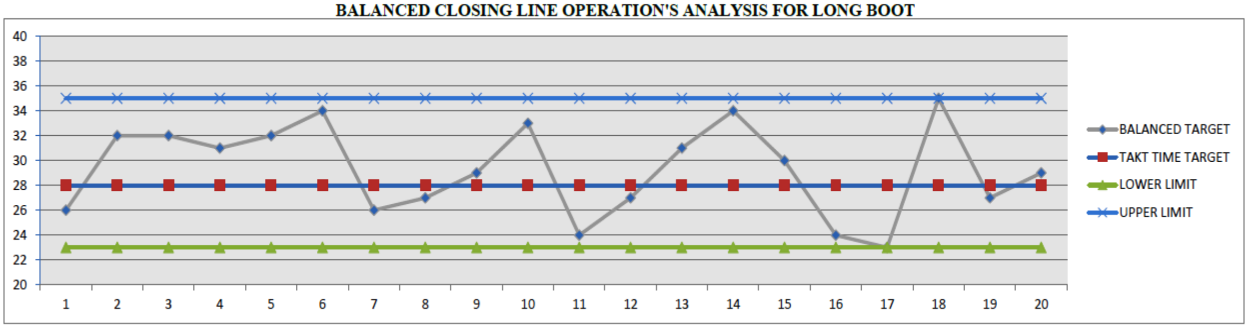


Figure 45 GRAPHICAL REPRESENTATION OF LONG BOOT # 1 LINE BALANCING

4.5.5.10 Formulation for Line Balancing Experiment on Long Boot Article # 2

Now team will calculate takt time for the article # 1

SAM of the article = 52.95 min.

Planned Manpower = 20 Person

Now calculating takt time according to formula.

SAM of Article = **52.95 min.**

No. of Person = **20 person**

Takt time = **2.65 min.**

Now according to takt time each work station needs to produce output of

$$\text{Target/Hour} = \frac{60}{2.65} = \textbf{23 pairs / Hour}$$

U.C.L = 22 pairs X 1.20 = 28 Pairs

L.C.L = 22 pairs X .80 = 19 Pairs

Takt Time = 23 Pairs

4.5.5.11 Line balancing of Long Boot 2

LAY OUT

STYLE NO : LB-2 **S.M.V : 52.95** **LINE NO :** **M/PWR: 20**

21	MAN	68 Trim Lining 69 Trim Fur Lining (Medium) 70 Cleaning (Winter)	0.68 1.36 2.82	4.86 **12**					22
19	Man	61 Fit Lining With Upper (Medium)	2.84	2.84 **21**	MAN	68 Trim Lining 69 Trim Fur Lining (Medium) 70 Cleaning (Winter)	0.68 1.36 2.82	4.86 **12**	20
17	SNL	55 Top Stitch Straight 58 Ts Zip Cover Piece (Mid) 62 Top Stitch 2nd seam Zip & Collar All Aro 63 Zip Reinforcment Stitch	0.72 0.56 2.00 0.30	3.58 **17**	Man	59 Cement Upper (Full) Medium 60 Cement Lining (Full) Medium 64 Cement stiffner 65 Cement Counter Edge for fitting	1.18 1.3 0.22 0.3	3 **20**	18
15	ZZ	47 Zig Zag Quarter Lining Front Seam(M) 48 Join Quarter Lining Bk Seam (Medium) 49 Join Qrter Lining With Vamp Lining 51 Zig Zag Lining Lock	0.66 0.80 0.56 0.40	2.42 **25**	Man	52 Edge Cementing (Small) 53 Edge Cementing (Small) 54 Edge Fitting (Small) 56 Cement Zip Cover Medium	0.68 0.68 0.88 0.68	2.92 **21**	16
13	Man	42 Edge Cementing (Medium) 43 Edge Fitting (Large) 44 Repunch 45 Insert Rivet With Cap	0.88 0.90 0.12 0.48	2.38 **25**	MAN	46 Punch Rivet 50 Taping Vamp Zig Zag Seam 64 Cement stiffner 65 Cement Counter Edge for fitting	0.2 0.52 0.22 0.3	1.24 **48**	14
11	Man	34 Edge Cementing (Small) 35 Fold Edge Small 36 Trim Zip 57 Fit Zip Cover With Fur Lining Medium	0.68 0.80 0.14 0.36	1.98 **30**	Man	37 Cement Zip (Medium) 38 Cement Upper Fr Zip Fit (Medium) 39 Fit Zip (Medium) 40 Trim Zip	0.5 0.6 1.08 0.28	2.46 **24**	12
9	MAN	26 Spray (Any small Component) 27 Whole Fitting (Medium) 28 Fold Edge Large 29 Hammering Edge	0.44 0.66 0.90 0.72	2.72 **22**	Man	30 Edge Cementing (Small) 31 Edge Cementing (Small) 32 Edge Fitting (Small) 66 Fit stiffner to back counter (Moccasin)	0.68 0.68 0.88 0.44	2.68 **22**	10
7	Man	20 Cement Vamp Edge for fitting 21 Cement Upper Edge For Vamp Fit 22 Fit Vamp To Upper (Boots) 25 Fit tape to vamp sides	0.44 0.44 1.22 0.54	2.64 **23**	SNL	24 Top Stitch Deco Vamp 33 Top Stitch Straight 41 Top Stitch Zip Edge (Medium) 67 Toe Tacking	0.88 0.72 1.14 0.44	3.18 **19**	8

5	SNL	13 Top Stitch Deco On Quarters 18 Ts Back Counter Edge 19 Top Stitch Deco Back Counter 23 Ts Vamp Edge(Booty)	0.40 0.66 0.56 1.18	2.8 **21**	Man	15 Cement Counter Edge for fitting 16 Cement Uppr For Bk Counter Fitting 17 Fit Back Counter To Upper (Boots)	0.3 0.44 0.76	1.5 **40**	6
3	SNL	5 Join Qrter Frnt/ Bk Seam (Medium) 7 Join Qrter Frnt/ Bk Seam (Medium) 11 Top Stitch Straight 1 12 Top Stitch Deco On Quarters	0.66 0.66 0.50 0.80	2.62 **23**	TAPE	6 Taping Quarter Front/ Bk Seam 8 Taping Quarter Front/ Bk Seam 9 Edge Cementing (Medium) 10 Edge Fitting (Medium)	0.3 0.3 0.88 0.72	2.2 **27**	4
1	MAN	1 Allign Backer (1 Component) 3 Fit Tape To Toe	1.92 0.36	2.28 **26**	PRESS	2 Rotary Press 1 Cycle 4 Toe Puff 14 Fit Fusing On Collar (Single Pc) Boots	1.53 0.56 1.08	3.17 **19**	2

4.5.5.12 GRAPHICAL REPRESENTATION OF LONG BOOT # 2 LINE BALANCING

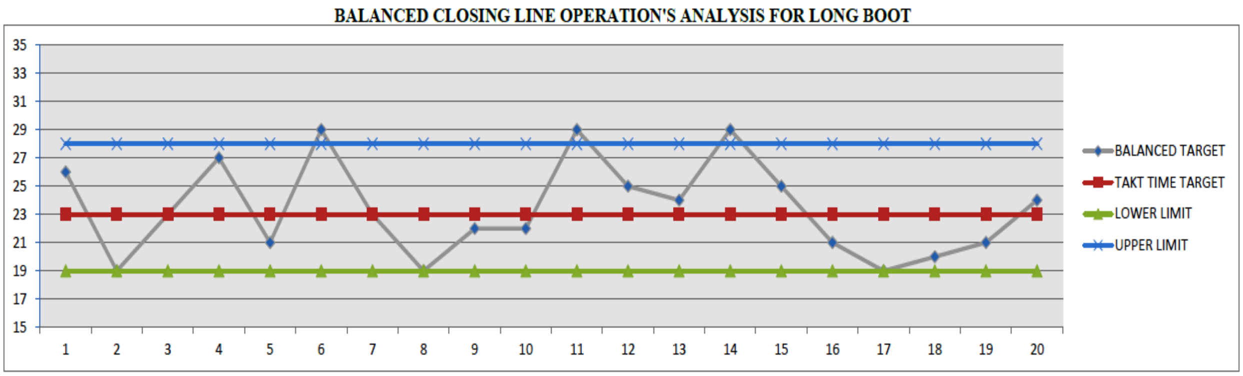


Figure 46 GRAPHICAL REPRESENTATION OF LONG BOOT # 2 LINE BALANCING

4.5.6 EFFICIENCY ANALYSIS AFTER LINE BALANCING

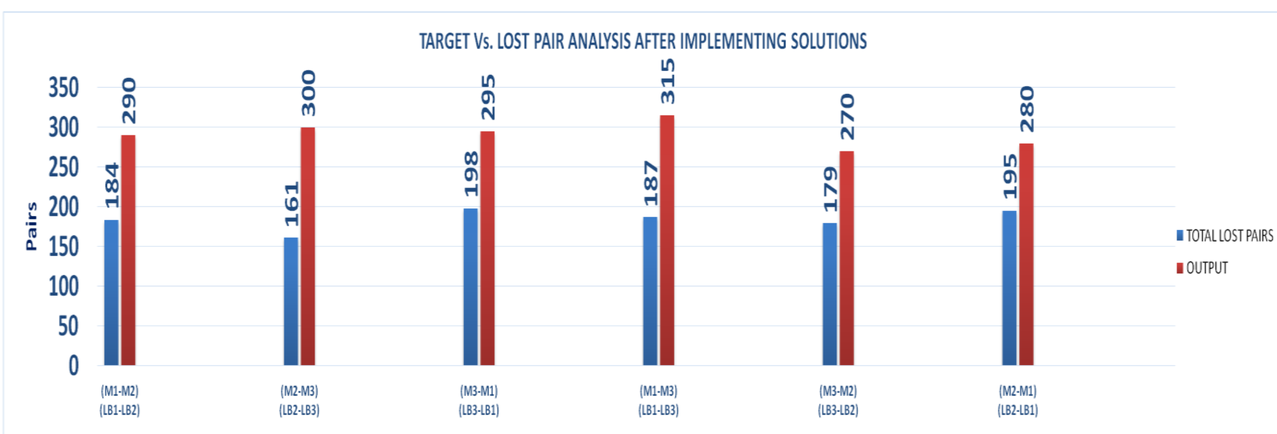


Figure 47 EFFICIENCY ANALYSIS AFTER IMPLEMENTING SOLUTIONS

Now line under observation has been divided into2 specialized cells containing 20-22 worker/cell which was previously 45 worker/line. After line balancing of each cell project team has achieved average efficiency of 2 cells at **63%**. After implementation of line balancing & cellular system project has reduced the overall manpower from 45 workers to 20 workers in 2 cells i.e. 5 workers reduced. Cell 1 & 2 is running moccasin articles & long boot articles respectively.

Project team has also removed& merged some non-value added operations using awareness & training sessions that are,

- **Re-counting**
  This operation has been removed by Loss Awareness Session with cutting department's feeding section, conduct a training session on Right First Time **(RFT)**so that they may provide proper pair wise feeding to closing line.
- **Pairing & Packing**
  This operation has been removed by Loss Awareness Session with Closing line's workers & foreman & conducts a training session on Right First Time **(RFT)** so that they can move the production pair wise from start till end.
- **Cementing & Fitting Heel Grip**
  This operation has been removed by training the Closing line's stitching operators on direct stitching.
- **Hammering After Taping**
  This operation has been removed by introducing the taping machine in closing line which can apply tape with required pressure that can flattened the seam joint.
- **Numbering**
  This operation has been merged with backer fitting operation with minimum change in SAM of backer fitting.
- **Vamp Pairing**
  This operation has been removed by Loss Awareness Session with cutting department's feeding section, conduct a training session on Right First Time **(RFT)**so that they may provide vamp in size wise bundles.
- **Thread Trimming / Thread Burning**
  This operation was removed by introducing auto cutter installation on sewing machines.

Now the team will train the production team to use this line balancing formulation to work over the rest of closing lines to improve their efficiency accordingly.

4.5.7 Design out Comparison

Design out comparison has proved that efficiency of the specialized cells after line balancing has improved & with respect to that lost minutes, throughput time & changeover time has been reduced for both moccasin & long boot cells.

4.5.7.1 Closing Line's Performance before Implementing Solutions

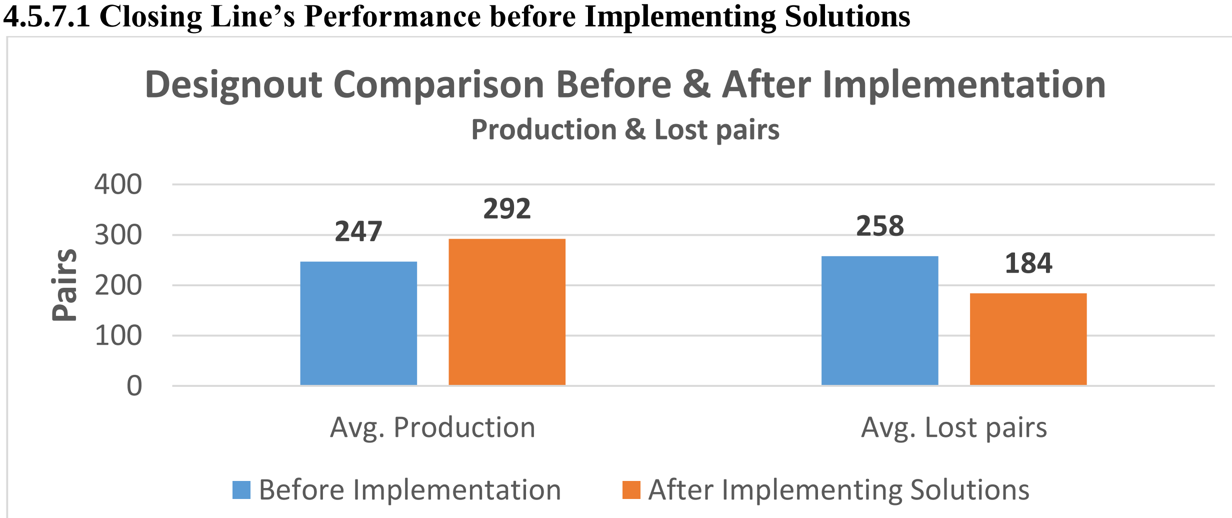


Figure 48 Closing Line's Performance before Cellular System & Line Balancing

4.5.7.2 Closing Line's Performance after Implementing Solutions

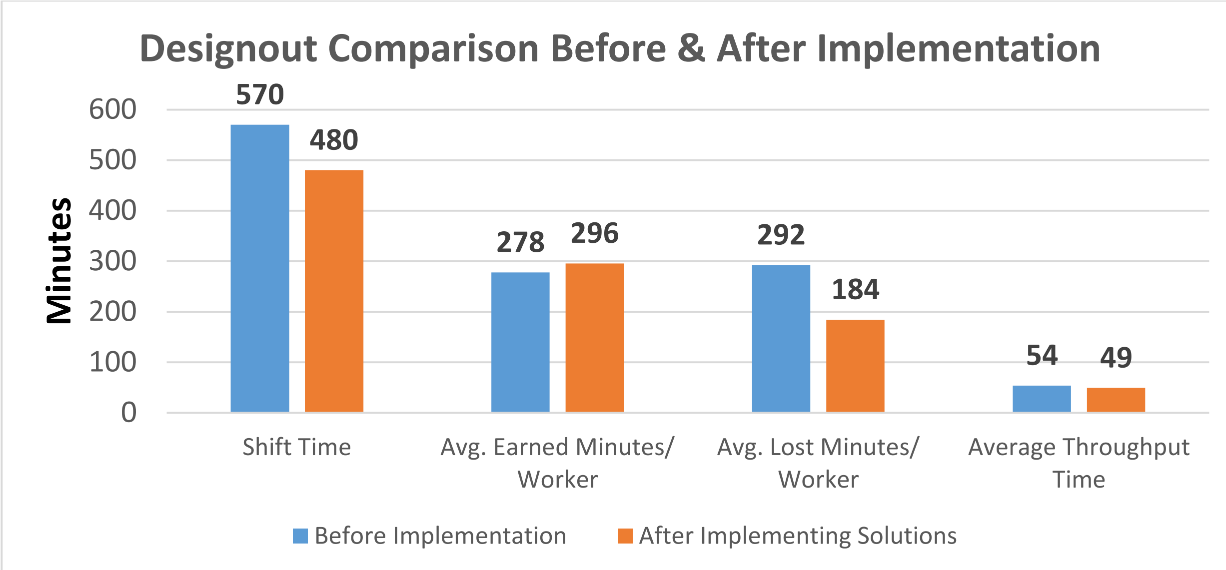


Figure 49 Closing Line's Performance after Cellular System& Line Balancing

4.5.8 Process Capability Analysis

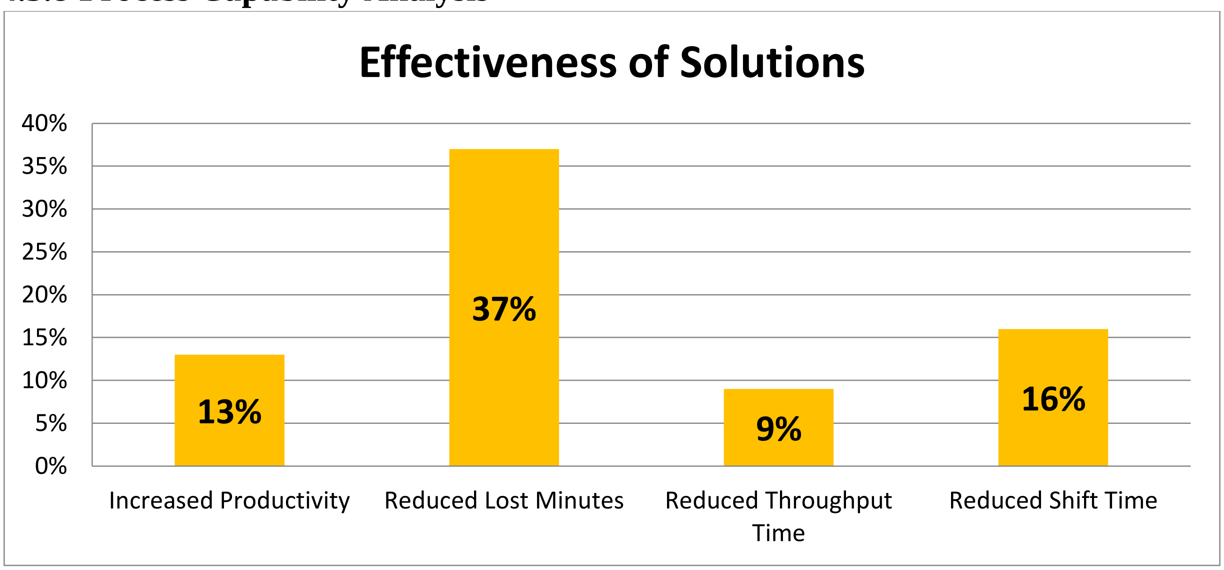


Figure 50 Process Capability Analysis

Closing line's improvement after cellular system & line balancing is representing that overall efficiency of both cells has increased by **16%**that reduced the lost minutes of the cells by **37%,** it also reduced the throughput time of the cells by **9%** because of eliminating non value added operations & training of the workers.

4.6 Control Phase

The three major steps of the control phase will be to standardize and integrate the process improvements done, implement controls, document and close the project. This all is done so the improvement become business as usual. Some of the goals of this phase of DMAIC are

- Identify methods of control to ensure that improvements are sustained over the long term
- Develop and document a control plan encompassing all activities and documentation required to sustain project and process improvements
- Establish provisions to monitor process performance and thus verify that the project improvements are maintained
- Hand off to the process owner a completed, finished, and wrapped-up project with properly documented instructions and procedures if changed.

Now after completion of on floor activities, project team has concluded that for the purpose continues improvement, implementation of improved parameters to the rest of closing lines & control the improved lines we need to prepare a training school from where we can have multi skilled workers & also conduct training session for production team so that they can be guided that to balance the line.

4.6.1 AAMT (Advance Analytical Method of Training)

4.6.1.1 Orientation

Company Rules

- hiring procedure, allocation, payment method, leave policy& procedure, termination procedure, attendance system, dress code

Regulation Policy

- attendance, cleaning, work station, leave sop, reporting structure, strict follow up of time schedule

Attitude & Behavior

- objective of work, ethics of work, working environment, benefits of pleasant working environment, personal perception of behavior, effects of good behavior on working, bad working attitude & behavior, dealing with subordinates, supervisors

4.6.1.2 Product knowledge

- Types of machine: manual, automatic machines, profile stitch machines, stitch types, machines w.r.t stitch types,
- Parts of machines, needle type to be used in machines,
- Machines w.r.t. needles
- Machine cleaning & work station organization

4.6.1.3 Machine / Manual Operations' knowledge

- Types of machine: manual, automatic machines, profile stitch machines, stitch types, machines w.r.t stitch types,
- Parts of machines, needle type to be used in machines,
- Machines w.r.t. needles
- Machine handling & operational training
- Machine cleaning & work station organization
- Cementing, fitting & folding operations' training

4.6.1.4 Safety Precautions:

- Needle guards, eye guards, covered pulleys, nude wires.
- Stop machine before stand. Start machine after checkup.
- Parts not damaged, procedure for over lock machines.

4.6.1.5 Stamina Build up:

- Stamina check, SC of operator, hourly status, day production, and quality problem (altered pcs of operator) objective of this observation.

4.6.1.6 Method & Quality:

- Sections in stitching, Different types of operations, and method on each operation Importance of methods, relation b/w method, SMV, & target, Quality points to be considered at operation.

4.6.1.7 Final Test:

- Method verification, machine knowledge, discipline rules awareness, stamina performance, SC %, procedure follow up at production start up, safety precaution awareness, machine knowledge, attitude behavior during training , discipline rules awareness.

4.6.1.8 Handover to Production:

- After successful completion of test the operator will handed over to production.

4.6.1.9 Training Session with Production Team

Project team conducted training session with production team for 2 weeks regarding below mentioned points,

- SAM (Standard allowed minutes) calculation
- Capacity calculation
- Preparation of process breakdown
- Line's target per hour & per shift calculation
- Calculation of operational target per hour
- Takt time calculation
- Balancing the line by adjusting the operations according to takt time target per station.
- Layout planning as per balanced line

4.6.2 Process Management Chart

The first step of control phase that we did was to make a proper process management chart so that the control phase is systematic. This Standardization is what allows high quality to occur on a reliable, sustained basis and guarantee for the success of our improvements. This chart is a framework that can be quickly changed and communicated to all workers, allowing for rapid response when new change is communicated. The spirit of this step is definition of a work method wherein all variables of the method have been specified in detail. Process management identifies the need for a project to improve or design a process. When the project is complete, the improved or redesigned process reenters the process management system.

The other major factor considered studied and applied in the control phase for the process management is the PDSA cycle that comprises of

- PLAN: Plan what needs to be monitored.
- DO: Implement the monitoring and control activities.
- CHECK: Assess whether the process is meeting performance expectations.

- ACT: Take action to address any performance problems that arise.

As our major focus was to review overall process documentation we were using process management charts.

Process Management chart	
Process	**Key Performance Indicators**
SEWING (CLOSING)	Line Efficiency
	Man to Machine Ratio
	Average Article Changeover Time
	Quality To Production
	Down Time Percentage

Table 2 Process Management Chart

In order to analyze, maintain & improve the current process project team prepared & suggested the above mentioned key performance indicators for closing lines to production team.

4.6.3 SWOT Analysis

After the completion of the project we again did a SWOT analysis to explore our implementation and have a solid future conclusion. The table is listed below which shows our strengths weaknesses and tells the opportunities and highlights the threats.

STRENGTHS (INTERNAL)	WEAKNESSES (INTERNAL)
Strong Coordination with DMAIC team, Strong support from production team, Dedication, Motivation, Team work & Technical knowledge of team	Time Management
OPPORTUNITIES (EXTERNAL)	**THREATS (EXTERNAL)**
In-depth knowledge of closing process of footwear manufacturing & its optimization opportunities, targeted process improvement generated more saving	If no attention will be paid to improved system, productivity loss will increase again

Table 3 SWOT Analysis

4.6.4 Cost/Benefit Analysis

Cost& Benefit analysis (CBA) is a tool used to take business decisions. It is a tool which is used to analyze a single option, or compare more than one option to select the most suitable alternative. CBA estimates complete cost of a particular decision, then comparing it to the estimated benefits of that decision. CBA is not only used for a business, as government uses it to evaluate different strategy choices. CBA can be performed using very complicated financial models that take into account not only concrete costs and benefits, but also factor in hard to quantify intangibles such as employee morale and customer satisfaction. Another cost included in a CBA is the opportunity cost of not pursuing other alternatives.

Now as the team has finalized its working for the closing lines, now the project team will be making the cost & benefit of the closing lines before & after implementation of improvement tools.

Operating cost per day per machine of the organization has been provided to project team i.e. PKR-900/- for 8 hour working (Standard working hours). But production is running continuously at 9.50 hours/day so operating cost per day per machine will become PKR- 1068/- Now on the basis of this operating cost per day per machine project team will calculate cost of manufacturing per piece before & after implementation of improvement tools.

4.6.5 Cost Saving:

COST SAVING			
Particulatrs	**UOM**	**Values before Implementation**	**Values after Implementation**
Avg. Production / Line Before Implementing Solutions	Pairs	247	292
Avg. Worker / Line Before Implementing Solutions	Person	45	45
Avg. Working Hours Before Implementing Solutions	Hours	9.5	8.0
Total Available Minutes Before Implementing Solutions **(Shift Minutes * No. of Workers)**	Mins	25650	21600
Cost of Sewing Line Before Implementing Solutions **(Total Available Mins * Cost Per Minute)**	PKR	89775	75600
Sewin Line Per Pair Manufacturing Cost Before Implementing Solutions **(Cost of Line / No. of Pairs Produced)**	PKR	363	259
Sewin Line Cost Saved / Pair	**PKR**	**105**	

Figure 51 Cost Saving at MANUFACTURING

Now as per above analysis manufacturing cost per day per piece has been calculated on the basis of daily production figure before implementing the improvement tools. Daily average production figure for combine moccasin & long boot articles has been observed as **247 pairs/ day,** with number of operators **45/line** at cost per minute for sewing line is **PKR- 3.5/-** so on the basis of gathered & calculated data cost of manufacturing per piece **PKR. 363/-**.

Now daily average production figure for the line after implementing solutions has been observed as **292 pairs/ day,** with allocated number of operators **45/line** at cost per minute for sewing line is **PKR- 3.5/-** so on the basis of improved system, reduced cost of manufacturing per piece in sewing line is observed as **PKR. 259/-**.

Finally the cost per pair for sewing line after implementing solution has been reduced by PKR- 105/-.

5. CONCLUSION & RECOMMENDATIONS

After satisfaction from the project outcome and achievement of its main objects, the project was closed. Conclusions that can be drawn From Six Sigma Project are:

- Increasing productivity with the available resources is the prime concern of the footwear manufacturing Industry. This shoe manufacturing industry is the largest shoe manufacturer & exporters in Pakistan. To make the maximum utilization of the available capacity industry must set the thing in order. In this case scenario Six Sigma is considered to be the best tool to identify the process losses & increase the overall productivity.
- Industry is facing in closing (sewing) section to meet the overall industry's requirement to make optimum utilization of available capacity.
- Currently the closing line's average efficiency is monitored as **47%**producing on average **247 pairs/line** with the manpower **45 worker/line.**
- Currently there were no operational standards available to calculate take time or target & efficiency for each line. The lines were following management provided fix estimated targets.
- There was no concept of line balancing, workers were allocated to the operations on the basis of line's foreman's experience. Therefore closing lines were following non-systematic way of production & therefore management was totally unaware of their production capacity of closing lines.
- In the define phase thought map was made to define that in each step of DMAIC how the project will move forward? After that a project charter was made to bring all the management & project team on one page that everyone will be focused on the project output. After that SIPOC model was prepared to express the complete process flow from start till end. This model provides project team to understand the overall process & find area of improvement. After that voice of customer VOC is defined that what are the customer's requirement, preferences & expectation regarding the project under consideration. VOC defines the customer according to its demands & expectation. It provide the basis to focus & target the areas where the projected customers have their interest. It provides strong basis to implement DMAIC methodology for improvement. In next step project team prepared a communication plan that is inducted to channelize the communication system between every individual who is the part of the project.
- In measure phase the project team elaborated every single aspect of the project under consideration. First of all it is defined that how measure phase will move on? Than process mapping for moccasin & long boots were prepared to make an understanding about the process flow of different constructions. A data collection plan was prepared to get the data systematically. The data extracted through data collection plan help in elaborating problem more clearly. On the basis of data collection plan, measurement system analysis was made that defined the current system situation. For the current state analysis project team prepared the complete operational data bank for shoe construction in closing line. After completing operational SAM data bank operational breakdown for different moccasin & long boot constructions is prepared to identify the article's SAM, target & takt time. On the basis of operational breakdown target project team make an analysis for target vs. lost pair analysis to understand the current position of the closing lines. After lost pair analysis project team defined the current system capability. Finally project team made a focused problem statement.

- In analyze phase initially it was defined how to make data & process analysis. Ishikawa diagram is prepared to identify the process losses & targeting the main among them. Through this diagram it was identified that the two main loop holes we have in the system are Poor line balancing & Changeover.Prioritization tools is used to understand that how this poor line balancing makes an impact over the closing line. After that the project team 5 Whys analysis to analyze the root cause of the problem. When the root cause analysis has been made after that project team made a failure mode & effect analysis. Failure Mode and Effects Analysis (FMEA) is a technique intended to identify and understand possible failure modes and their causes and the effects of failure on the system, for a given process. FMEA measure the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action. Project team prepared FMEA worksheet for closing line so as to find out the potential failure modes & causes behind them. From the above failure mode & effect analysis (FMEA) worksheet for closing line project team have found out that causes having maximum Risk Priority Number (RPN) are 1. Hypothetical Operational targets 2. Unavailability of formulation of line balancing 3. Frequent changeover.
- In improve phase first the project team prepared the changeover time comparison that defined the production loss due to change in similar type of construction & in other construction. Project team found that when article in closing line changes between the similar construction moccasin to moccasin lost pair percent moves to **48%**, when article changes from long boot to long boot lost pair percent moves to **50%** & when article changeover is made between moccasin to long boot lost pair percent moves to **53%.** Product team after analysis defined that product cellular system can reduce this lost pair percentage & improve overall efficiency. Next the project team prepared a poka yoke model that can minimize the error margin while balancing the line based on the takt time. After that project team prepared a detailed formulation & prepared a model by which line balancing can be done article wise based on takt time. After making trial over 5 different moccasin to long boot changeover production improve to **62%** efficiency. Project team made a design out comparison to identify the stats of before & after implementation**.** Basis on that comparison project team has found that overall efficiency increased by **13%** reduce lost minutes by **37%** reduced throughput time by **9%**. After that project team calculated manufacturing cost per piece before & after implementation. Before implementation of solutions manufacturing cost per piece was calculated as **PKR. 363/-**& after implementation it reduced to **PKR. 259/-**. This impact reduced cost per pair in sewing line by **PKR- 105/-**
- In control phase project team planned to maintain & further improve the system using PDCA model.

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