Improving Sewing Quality in Ready-Made Garment Industry of Bangladesh: A Case Study

By

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A project is submitted to the Department of Industrial and Production Engineering (IPE), Bangladesh University of Engineering and Technology (BUET), Dhaka, in partial fulfillment of the requirement for the degree of Master of Engineering (M. Engg.) in Industrial and Production Engineering.

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CERTIFICATE OF APPROVAL

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Habibur Rahman

Date: 24th March, 2019

To the Almighty

To my Family

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ABSTRACT

At the present age, product quality is not only the customer requirement, it is also a competitive advantage for a business organization. Every business organization desperately trying to produce its products with best quality with low production cost. In the recent years, sewing quality in garments industries gets most priority from both producer and customer ends. Defects reduction is the first step to improve sewing quality and to reduce production costs in garments industries of Bangladesh. Higher quality can be achieved by reducing alterations in sewing processes in garments industries. To gain competitive advantages companies are giving more emphasis on assuring the best quality in sewing processes besides productivity and production cost. Identifying different sewing-defects and addressing them properly is the way of getting better quality, higher productivity and lower production cost in garments industries. This case study represents the application of the well-known and frequently used tool of Six Sigma, named DMAIC methodology in identifying and reducing or eliminating the major defects with their root causes in sewing processes in garments industries. The five phase of DMAIC methodology named Define, Measure, Analyze, Improve and Control; this approach minimizes defects analytically. Pareto Chart Analysis Diagram was applied to prioritize top defects based on their nature and frequency. Brainstorming and literature review also helped to get some potential solutions to address this problem. In remedial action, a pilot run was conducted in some selected sewing lines the selected factory and significant result was found in terms of quality improvement in the scale of Defects per Hundred Units (DHU) and efficiency level also.

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CHAPTER 1
INTRODUCTION

1.1. Introduction

At the present age of globalization and rapid growth of information technology, people are more aware of the changes of their surroundings and they get affected more quickly and easily and hence customer's choices are changing frequently. Fashion industries have to frequently change the design of products to keep pace with the customer's choice or requirement. Quality is the reflection of customer choice or requirements. Quality can be described as the degree of excellence or conformance to the requirement.

To cope up with the frequent change of product specifications, to achieve the required level of quality is one of the major challenges in garments industries of Bangladesh. Low level of quality, increases the cost of production and decreases the productivity. Now a day's, apparel manufacturing industries are seeking competitive advantages each over others by achieving efficient and low cost production system with proper resource utilization while without compromising any level of quality. So, it is obvious that better quality is undoubtedly a competitive feature for any garments manufacturing industry. In garments manufacturing industries, many different types of defects in sewing process occur, and without proper addressing them, it is almost impossible to achieve required quality level. The defects nature and their root causes are not similar to each other. To get permanent solutions to reduce or eliminate the defects, it is very crucial to identify their root causes. If once root causes are identified, it becomes easy to get solution of any defect. DMAIC is one of the effective tool of Six Sigma to trace the roots of any defect. This paper represents the application of DMAIC methodology for identifying and solutions making of defects in sewing processes in garments manufacturing industries of Bangladesh to improve the workmanship quality of sewing processes.

1.2. Background and Present State of the Problem

The ready-made garments (RMG) industry is the backbone of the economy of Bangladesh and works as a catalyst for the development of the country [1]. At present, about 4 million people are directly employed in the RMG sector and this sector covers more than 80% of foreign export value. In 2017-18 fiscal years, the export value of the RMG sector is about 30.61 billion dollars out of the total export value of 36.66 billion dollars. Improvement in quality assurance system of RMG industry can play a vital role in improving the productivity as well as economic development for the country and it can add strength to global competitiveness in the global textile market through improving quality as the low quality means high cost and loss of competitive position [2]. The demand for higher value at a lower price is increasing and to survive, RMG manufacturers need to improve their operations by producing right-first-time quality [3]. In RMG industries of Bangladesh, the low sewing-quality is still now a major problem. So, to improve sewing-quality by address this problem effectively and efficiently, it is essential to find out the root causes of this problem to remove or fix these causes [4].

DMAIC model is a systematic method for analyzing and improving business processes. It is an integral part of a Six Sigma initiative, but in general can be implemented as a standalone quality improvement procedure or as a part of other process improvement initiatives [5]. DMAIC (Define, Measure, Analyze, Improve, and Control) methodology of 6 Sigma refers to a data-driven quality strategy for improving processes can be used to improve an existing business process.
DMAIC methodology can be an effective model to address this problem to get the desired output or result.

1.3. Objectives with Specific Aims and Possible Outcome

1) To improve the level of workmanship quality of sewing process on the scale of DHU (Defect per Hundred Units).

2) To show the productivity improvement in terms of efficiency level in sewing section as a result of garments quality improvement.

CHAPTER 2
LITERATURE REVIEW

2.1. Introduction

This chapter is to explore and gather all information in order to understand clearly about the DMAIC methodology, Quality, Defect, Defect per Hundred Units (DHU), Fish-bone diagram, Productivity, Efficiency, Garments Manicuring Steps etc. The information comes from reference books, journals and thesis. These sections are mainly concerned about related knowledge about identifying & removing of various sewing defects, improving quality & productivity which reflect the level of workmanship quality improvement of the process of sewing section. This particular area is discussed to give better understanding on what is purpose of this research.

2.2. Quality

The term 'Quality' is very common to all. Quality may be described as the degree of excellence or conformance to the requirements. According to the online business dictionary quality may be defined in manufacturing, as a measure of excellence or a state of being free from defects, deficiencies and significant variations. It is brought about by strict and consistent commitment to certain standards that achieve uniformity of a product in order to satisfy specific customer or user requirements. A simple and more general definition of quality is given in 1974 by Juran is "Quality is fitness for use" [6].

2.3. DMAIC

DMAIC is an acronym that stands for Define, Measure, Analyze, Improve and Control. DMAIC is a data-driven quality strategy used to improve processes [7]. It is an integral part of a Six Sigma initiative, but in general can be implemented as a standalone quality improvement procedure or as part of other process improvement initiatives such as lean [7]. It is the most preferred tool that can help improving the efficiency and the effectiveness of any organization. The base of this problem solving tool is founded by Shingeo Shingo, during the development of Poka Yoke [8]. Six Sigma's most common and well-known methodology is its problem-solving DMAIC approach and this DMAIC methodology can be thought of as a roadmap for problem solving and product/process improvement. It is an effective lean tool to identify the root cause of any problem to address the problem. In garments manufacturing industries, there are many problems regarding defects in sewing process of and their roots are difficult to find out properly and hence DMAIC methodology can be an effect tool to apply to solve this problem. DMAIC methodology helps identify and diagnose the problems and their root causes in a systematic way. So, for better identifying, defining, analyzing of defect related problems in sewing processes and improving the quality level in garments manufacturing industries DMAIC methodology can be a wise selection.

DMAIC methodology can be described as a roadmap by the following figure.

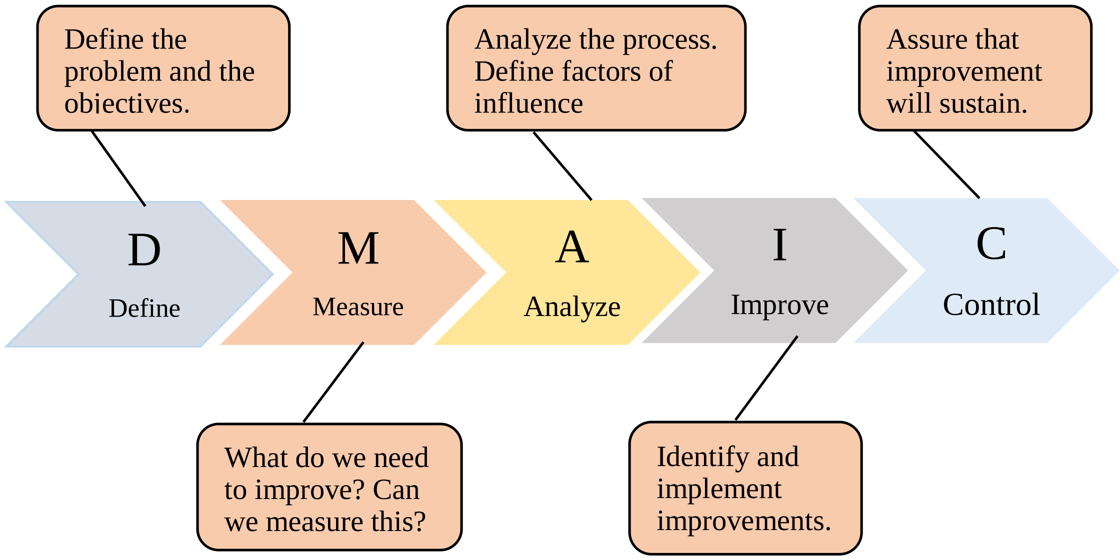

Figure 2.1: DMAIC Roadmap

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DMAIC approach can be described as step by step as firstly, define the problem, improvement activity, opportunity for improvement, the project goals, and customer (internal and external) requirements. Next, measure process performance. After measurement, one should analyze the process to determine root causes of variation, poor performance (defects). Hence, one can improve process performance by addressing and eliminating the root causes. Last but not the least, control the improved process and future process performance.

The steps can be summarized as follows.

1) Define: Stating the problem, specifying the customer set, identifying the goals, and outlining the target process are the main focus of this phase of DMAIC methodology of Six Sigma. It is very important in DMAIC to define the problem or project goals. The more specific the problem is defined the greater the chance of obtaining measurements and then successfully completing the project or solving the problem. The definition should describe the issue accurately with numeric representation. This phase focuses on clearly specifying the problems; the goals of the process improvement project what is the scope of the project and identifying the customers (internal and external) along with their requirements. The inputs to this phase usually come from the requirements or voice of customer, business and/or process. In addition, sometimes the requirements of employees are also effective to lead some six sigma improvement projects.

2) Measure: Deciding what parameters need to be quantified, working out the best way to measure them, collecting the necessary data, and carrying out the measurements by experiment are the main focus of this phase of DMAIC methodology. The main objective

of this phase is to collect the data that is relevant to the scope of the project. This phase focuses on identifying the parameters that need to be quantified, ways to measure them, collect necessary data and carry out measurement by different techniques. The operational definition of metric is devised. It gives common language & understanding of data being collected. Data Collection plan outlines what data to be collected. After data collection, data is analyzed to ascertain its nature through frequency distributions. The histogram can be used to understand the distribution of data. Depending upon data nature – Normal or Non – Normal, data - analysis tools are decided. Current Process capability is also an important aspect to be understood in this phase.

3) Analyze: Identifying gaps between actual and goal performance, determining causes of those gaps, determining how process inputs affect outputs, and ranking improvement opportunities are the main focus of this phase of DMAIC methodology. The main objective of this phase is to find the root cause of business inefficiency. It identifies the gaps between actual and goal performance, determine its causes and opportunities for its improvement. Analyze phase follows a drill down approach to reach exact root causes from various potential causes identified initially. This phase starts with exploring all possible causes to the main problem. The outcome of this phase is verified root causes – which need to be acted upon to improve the process. Analyze phase requires due care to identify & verify root causes. Because the effectiveness of process improvement through six sigma project lies on the correct identification of root causes. Commonly used tools in Analyze phase are Fishbone Diagram, Brainstorming, Histogram, 5 Whys, Hypothesis testing, Time series plots and Scatterplot.

4) Improve: Devising potential solutions, identifying solutions that are easiest to implement, test hypothetical solutions, and implementing actual improvements are the main focus of this phase of DMAIC methodology. This phase improves the process by determining potential solutions, ways to implement them, test and implement them for improvement. In this phase, process owners are consulted and improvements are suggested. Action plan for the improvement is circulated to relevant stakeholders. The improvement plan is designed to mitigate the risk and include customer feedback and satisfaction. With the formation of improvement action plan, implementation phase starts simultaneously. During implementation, actions are carried out, tested for effectiveness and implemented finally. Tools used to eliminate the defects are Brainstorming, Mistake-proofing (Poka Yoke) etc.

5) Control: Generating a detailed solution monitoring plan, observing implemented improvements for success, updating plan records on a regular basis, and maintaining a workable employee training routine are the main focus of this phase of DMAIC methodology. After the implementation of the solution or project there requires a number of controls to be put in place so that measurements can be taken to confirm that the solution is still valid and to prevent recurrence. The control measurements can be scheduled for specific dates, e.g. monthly, daily, and yearly, etc. The solution should also be well documented and any other related process documentation updated. The main objective of this phase is to generate a detailed solution monitoring plan. This plan

ensures that the required performance is maintained. It defines and validates the monitoring system, develops standards and procedures, verifies benefits and profit growths, and communicates to business. Hence, the main purpose of Control phase is to ensure – Holding the gains. During this phase, post-implementation results are evaluated. Progress is ascertained. And Changes are incorporated - if any, correction or modification is required. Control phase in most of the cases is a transition phase. Transition happens from current practices & systems into new practices. The most important part of this phase is to provide training on new changes to all relevant stakeholders.

2.4. Defect

A defect is associated with a quality characteristic that does not meet certain standards [9]. Defect can be described as non-conformance of a product or service with the specified requirements, or non-fulfillment of user expectations. A defect is a physical, functional, or aesthetic attribute of a product or service that exhibits that the product or service failed to meet one of the desired specifications. In a simple term, defect can be described as any deviation from the specifications defined for any product or services.

2.4.1. Types of garments defects

Garments defects can mainly be categorized as:

- Fabric defects.

These types of defects are usually found in fabrics and they do not occur in sewing lines.

- Workmanship defects:

These types of defects directly associated with sewing process in sewing production lines due to operator or process –tools and they can occur both in cutting and sewing section.

Trims, accessories and embellishment defects

These type of defects usually associated with label, sewing threads, button, zippers, print, embroidery etc.

Garments defects can further be divided into another three categories like:
Critical defects: These are the most serious defects that not allowed and goods with this defects usually are rejected. Major defects: These types of defects are also serious defects and not allowed more than a certain percentage depending on buyer requirements. Minor defects: These types of defects also not allowed but a certain percentage can be allowed depending on the buyer requirements.

2.5. Defect per Hundred Units (DHU)

It is a measuring scale of defect frequency per hundred units of any product. In garments manufacturing industries, DHU means number of defects found or detected per hundred units of garments inspected at end of the sewing production line.

This is also known as DPHU (Defects Per Hundred Units). DHU value is calculated using following formula –

Defects per hundred units = (Total defects found*100) /Total garments inspected

As for example, if 2000 pieces of garments are inspected and 350 defects are found, then the DHU will be as per following calculation by the formula:

DHU = (Total defects found or identified *100 / Total garments inspected) %

= (350 * 100 / 2000) %

= 17.5 %

2.6. The Cause and Effect Diagram or Fishbone Diagram

The Cause and effect diagram or Fishbone Diagram or Ishikawa diagram is a tool that helps identify, sort and display possible causes of a specific problem or quality characteristic. Dr. Kaoru Ishikawa, a Japanese quality control expert, invented this fishbone diagram. This diagram is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes. It examines why something happened or might happen by organizing potential causes into smaller categories. It can also be useful for showing relationships between contributing factors. One of the seven basic tools of quality, it is often referred to as a fishbone diagram.

This diagram referred to as the "Ishikawa diagram," and the "fishbone diagram," because the complete diagram resembles a fish skeleton. The diagram illustrates the main causes and sub-causes leading to an effect (symptom) [10]. It is a team brainstorming tool used to identify potential root causes to problems. In a typical Fishbone diagram, the effect is usually a problem needs to be resolved, and is placed at the "fish head" [10]. The causes of the effect are then laid out along the "bones", and classified into different types along the branches. Further causes can be laid out alongside further side branches [10]. The classic fishbone diagram asks teams to list and group causes under the categories of Man, Machine, Method, Material, Equipment, Environment etc. The process of categorizing potential causes allows teams to break down a complex problem and focus on different aspects of it. This diagram has variety of benefits.

It helps teams understand that there are many causes that contribute to an effect. It graphically displays the relationship of the causes to the effect and to each other. It helps to identify areas for improvement.

To start making a fishbone diagram, it is to write the main issue or problem to be analyzed in a box that is typically on the right edge of the page, halfway down the drawing area or page. A line called the "spine" or "backbone" should extend to the left starting from the edge of the main box. Next, angle branches off of the spine, each representing a cause or effect of the main issue. Each of these branches can contain additional branches. Most diagrams examine a similar set of possible causes for any issue analyzed.

Simple steps involved for making a cause-effect diagram are:

To start by naming the main problem or event and this usually goes at the head of the "fish" in the diagram.

To make categories for causes and create the "bone structure" of fish. Common categories include: men, methods, materials, machines and environment etc.

The list possible causes under each category including variations in a process or design.

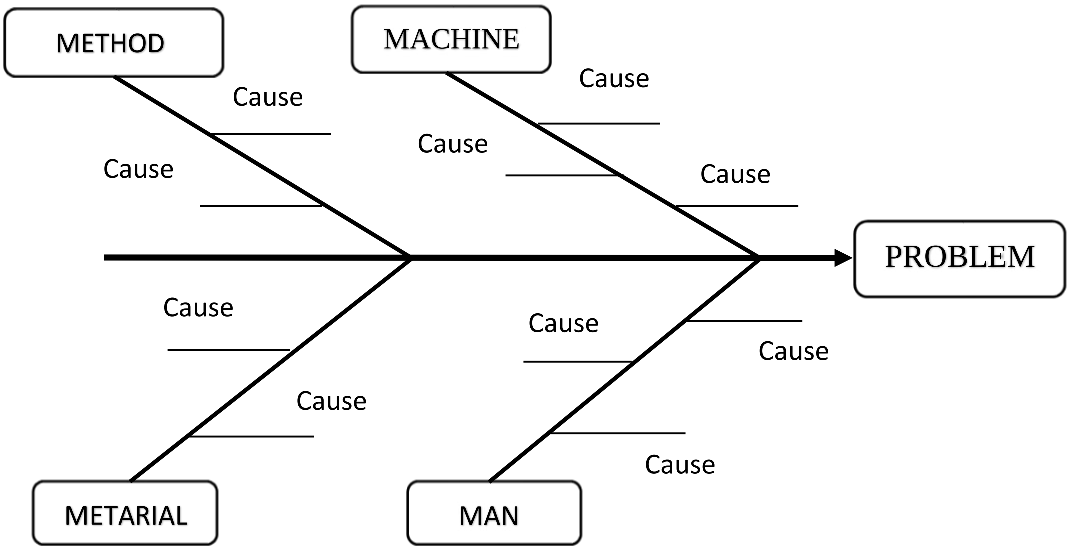

Figure 2.2: A typical cause and effect or fishbone diagram.

2.7. Productivity

Productivity may be defined as the ratio between output and input. Output means the amount produced or the number of items produced and the inputs are the various resources employed, e.g., land and building, equipment and machinery, materials, labor etc. [11]. Productivity is a measure of the rate at which outputs of goods and services are produced per unit of input (labor, capital, raw materials, etc.). It is calculated as the ratio of the amount of outputs produced to some measure of the amount of inputs used. Productivity measures are used at the level of firms, industries and entire economies. Depending on the context and the selection of input and output measures, productivity calculations can have different interpretations. Improving productivity can have connotations of economizing on the use of inputs — for example, adopting efficient production processes that minimize waste. Equally, improving productivity can have connotations of yielding more output — for example, using resources in activities or with technologies that generate more output. Conceptually, productivity is a 'supply-side' measure, capturing technical production relationships between inputs and outputs. But, implicitly, it is also about the production of goods and services that are desired, valued and in demand.

Productivity = Outputs / Inputs,

Productivity can be expressed as a physical measure (for example, number of garments produced per employee), and as a monetary measure (for example, thousands of dollars of output per hour worked). In principle, inputs can be broadly defined to cover people's time, their skills, land, raw materials, machinery and equipment, energy (for example, electricity) and so on. But, most commonly, inputs are defined in terms of: x labor (number of employees or hours of work) and x capital (buildings, machinery and equipment, etc.).

Productivity is said to be increased, when

1) The production increases without increase in inputs and

2) The production remains same with decrease in inputs.

2.8. Efficiency

The term "efficiency" is very much familiar with RMG industries in Bangladesh. It is the main tool or scale used to measure the performance of sewing machine operator. In RMG industries, usually a complete garment is to break down into a number of operations usually called sewing process to manufacture the garment by assembling the different parts by stitching seam with different types of sewing machines. And a ***standard allowed minute*** (SAM) time is assigned for each individual sewing process to perform by operators and helpers. SAM for a complete garment is sum of SAM of individual process performed by individual operator and helper. Efficiency is calculated in RMG sector in the following way:

Efficiency = (Allocated SAM / Actual time used) x 100%

Efficiency of an operator or process = SAM of the process / Actual time used by the operator to perform the process x 100%.

For example, if the SAM of a process is 0.75 minute and the actual time used by the operator is 1.15 minute, then the efficiency of this process or operator is:
Efficiency = SAM of Process / Actual time used x 100%

= (0.75 / 1.15) x 100%

= 65.22%

Line Efficiency: line efficiency is calculated in the following way. For example, if a SAM of a garment is 7 minutes and 20 operators and 8 helpers work to produce the garment in an assembly line and per hour production is 180 pieces in this assembly line, then the efficiency of the line is calculated as:

Efficiency of the line = (Production per hour x SAM) / (Total manpower x working hour x 60) x 100%

= (7 x 180) / (28 x 1*60) x 100%

= 75 %

SAM (Standard allowed minute): The amount of time required to complete a specific job or operation under existing condition, using the specified & standard method at a standard pace when there is plenty of repetitive work [12].

Standard time = (Average observed time x Rating %) + Allowance%.

Allowance: allowance is the additional time given to the performer with the standard basic time required to complete the job or process. Allowance may be different depending on the job nature. The common allowances in RMG industries are personal time, fatigue time, threads and needle changing time, bundle handling time etc. In RMG industries, allowance time are usually given 10% to 20% of standard basic time depending on the nature of the job.

2. 9. Pareto Chart

A Pareto chart, also called a Pareto distribution diagram, is a vertical bar graph in which values are plotted in decreasing order of relative frequency from left to right[13]. Pareto charts are extremely useful for analyzing what problems need attention first because the taller bars on the chart, which represent frequency, clearly illustrate which variables have the greatest cumulative effect on a given system. The Pareto chart provides a graphic depiction of the Pareto principle, a theory maintaining that 80% of the output in a given situation or system is produced by 20% of the input[13]. The Pareto chart is one of the seven basic tools of quality control. The independent variables on the chart are shown on the horizontal axis and the dependent variables are portrayed as the heights of bars[13]. A point-to-point graph, which shows the cumulative relative frequency, may be superimposed on the bar graph. Because the values of the statistical variables are placed in order of relative frequency, the graph clearly reveals which factors have the greatest impact and where attention is likely to yield the greatest benefit.

2.10. Basic Steps of Garments Manufacturing

Ready-made garment manufacturing involves some steps and techniques. The basic steps by which a knit garment is produced outlined as step by step process here:

Garments Design or Drawing Sketch

↓

Pattern design and Making

↓

Sample Making

↓

Pattern Making for Production

↓

Making Size Grading

↓

Marker Making for Fabric Cutting

↓

Fabric Spreading Cutting

↓

Fabric Cutting as Garments Parts (Cut Panel)

↓

Printing or Embroidering

↓

Sorting/Bundling

↓

Sewing or Assembling

↓

Ironing or Pressing/ Finishing

↓

Packing

↓

Dispatch

Figure 2.3: Sequential Steps of Garments Manufacturing.

2.10.1. Steps of garments manufacturing in a brief in tabular form

The garment manufacturing usually begins from the steps of receiving design or sketch from buyer and ends with delivery of shipment to the buyer for export. Between the first and last steps, some of steps like printing, embroidery or washing depends on only requirements of buyer to included or excluded. Among other steps, some of steps like size grading or sample modification can be customized by buyers.

The basic steps from first to last of manufacturing a garment in industry are described below in a brief in a tabular form.

Table 2.1: Operation of garments manufacturing.

SL No.	Operation Steps	Job	Method
01	Design/ Sketch	It is usually given by buyers to manufacturers containing sketches including measurements of particular styles.	Manual/ Computerized
02	Basic Block	It is an individual component of garments without any style of design .	Manual/ Computerized
03	Working Pattern	When a pattern is made for a particular style with net dimension regarding the basic block along with allowance then it is called working pattern.	Manual/ Computerized
04	Sample Garments	After making a sample, it is sent to buyer for approval to rectify the faults	Manual
05	Approved Sample	After rectify the faults, sample is again sent to buyers. If it is ok then , then it is called approved sample	Manual
06	Costing	Fabric Costing, Making Charged, Trimmings, Profit.	Manual
07	Production Pattern	Making allowance with net dimension for bulk production.	Manual /Computerized
08	Size Grading	If the buyer requires different sizes, so should be grade as S, M, L, XL, XXL.	Manual/ Computerized
09	Marker Making	Marker is a thin paper which contains all the components for different sizes for a particular style of garments.	Manual/ Computerized
10	Fabric Spreading	To spread the fabrics on table properly for cutting.	Manual/ Computerized
11	Cutting	To cut fabric according to marker dimension.	Manual/ Computerized
12	Sorting & Bundling	Sort out the fabric according to size and for each size make in individual bundles.	Manual
13	Sewing	To assemble a full garments.	Manual
14	Ironing & Finishing	After sewing a complete garment is treated with steam ironing & also several finishing processes are done for example extra loose thread cutting.	Manual
15	Inspection	Should be approved as initial sample.	Manual
16	Packing	Treated by polyethylene bag.	Manual
17	Cartooning	After packing, it is placed in cartooning for export.	Manual
18	Dispatching	Ready for export.	Manual

2.10.2. Flow chat of garments manufacturing at a glance

Garments manufacturing from first to last step can be described in flow chart which can give a better understanding of garments manufacturing procedure in garments industries. A typical flow chart of garments manufacturing is given blow-

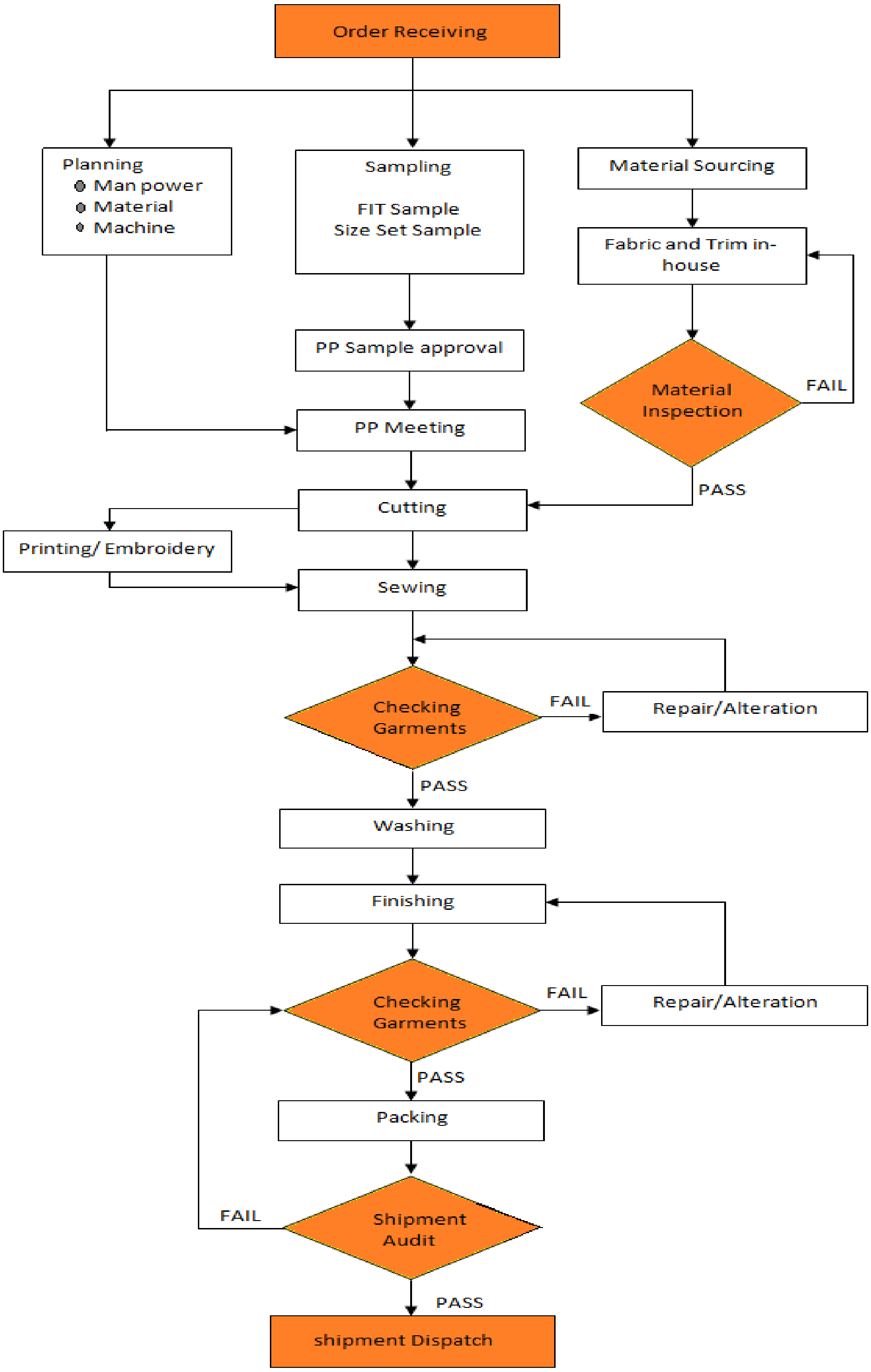

Figure 2.4: Process Flow Chart of Garments Manufacturing.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. Introduction

Research is defined as human activity based on intellectual application in the investigation of matter. According to Clifford Woody research comprise defining and refining problems, formulating hypothesis or suggested solutions, collecting, organizing and evaluating data by making reach solution [14]. Research may also be defined as systematic investigation intended to add to available knowledge in a form that is communicable and verifiable.

3.2. Nature of Research

Based on the nature, research may be classified as the following 3 categories [15]

1) Basic research

2) Applied research and

3) Action research

Basic research: Basic research (also called ***fundamental*** or ***pure*** research) has as its primary objective the advancement of knowledge and the theoretical understanding of the relations among variables. It is exploratory and often driven by the researcher's curiosity, interest, and intuition. It is conducted without any practical end in mind, although it may have unexpected results pointing to practical applications [16].

Applied research: It is also called field research. Kenneth D. Bailey (1982.21) said "applied research is research with findings that can be applied to solve problems of immediate concern" [17]. The primary aim for applied research is discovering, interpreting, and the development of methods and systems for the advancement of human knowledge on a wide variety of scientific matters of our world and the universe.

Action research: Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process [18]. Nature of this research is applied research.

3.3. Research Process in Flow Chart

The process which is followed to conduct this research is given below as in a flow chart [19].

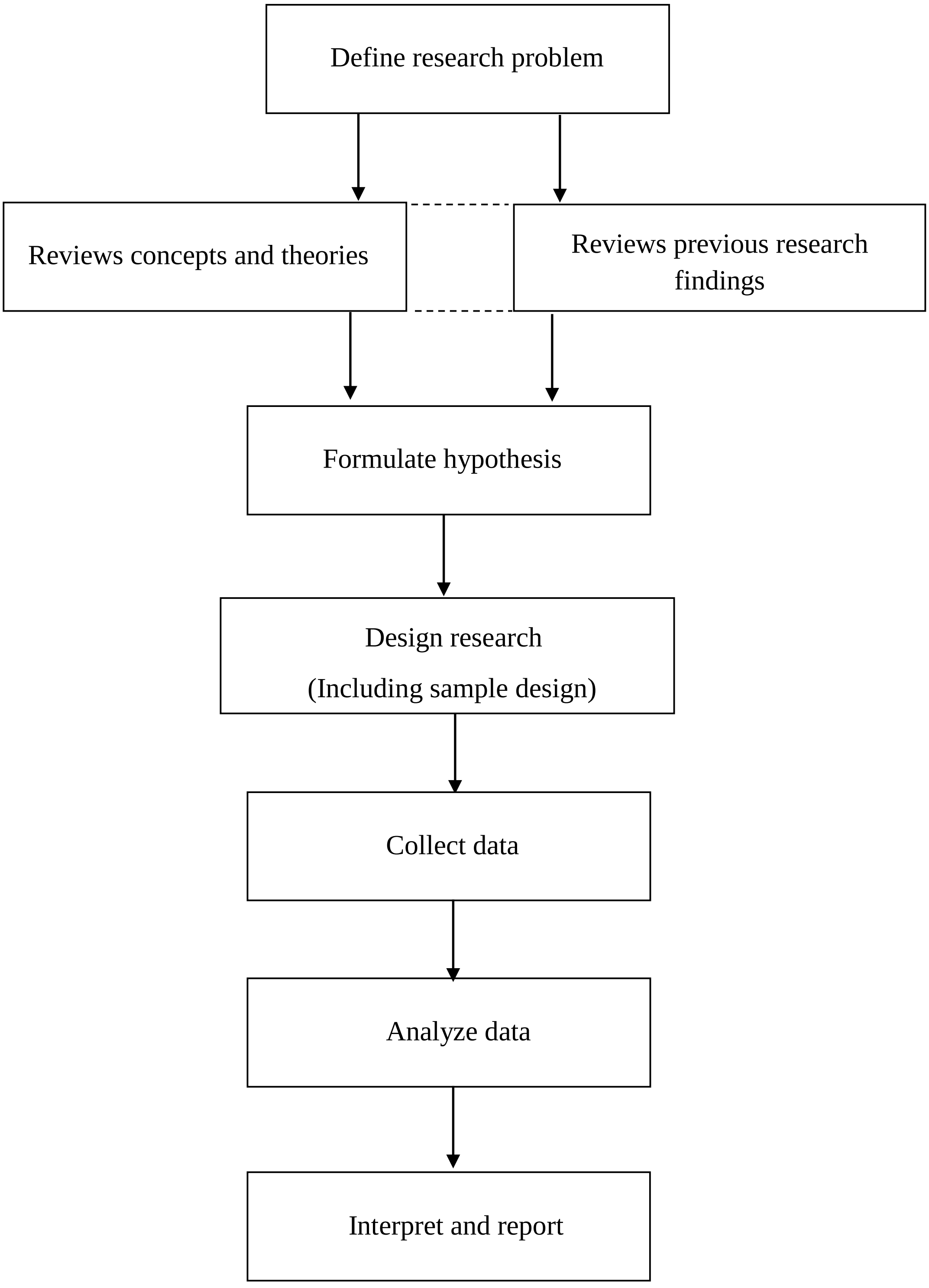

Figure 3.1: Flow chart of research process.

3.4. Research Methods

The goal of the research process is to produce new knowledge, which takes three main forms (although, as previously discussed, the boundaries between them may be fuzzy):

- Exploratory research, which structures and identifies new problems.
- Constructive research, which develops solutions to a problem.
- Empirical research, which tests the feasibility of a solution using empirical evidence [16].

In other view research may be classified as follows [17]:

- Case study
- Survey method
- Content analysis
- Cross sectional study
- Longitudinal study
- Ethnographic research
- Focused group discussion etc.

This research has been done by ***case study*** method.

3.4.1. Case study method

Introduction:

Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships.

Researchers have used the case study research method for many years across a variety of disciplines. Social scientists, in particular, have made wide use of this qualitative research method to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 1984, p. 23). Basically, a case study is an in depth study of a particular situation rather than a sweeping statistical. It is a method used to narrow down a very broad field of research into one easily researchable topic. This method of study is especially useful for trying to test theoretical models by using them in real world situation. Many well-known case study researchers such as Robert E. Stake, Helen Simons, and Robert K. Yin have written about case study research and suggested techniques for organizing and conducting the research successfully. This introduction to case study research draws upon their work and proposes six steps that should be used:

- Determine and define the research questions
- Select the cases and determine data gathering and analysis techniques
- Prepare to collect the data
- Collect data in the field
- Evaluate and analyze the data
- Prepare the report

- Step 1. Determine and define the research questions

The first step in case study research is to determine and define the research questions on the situation or problems upon which the case study will be conducted. The researcher establishes the focus of the study by forming questions about the situation or problem to be studied and determining a purpose for the study. Case study research generally answers one or more questions which begin with "how" or "why." The questions are targeted to a limited number of events or conditions and their inter-relationships. Careful definition of the questions at the start pinpoints where to look for evidence and helps determine the methods of analysis to be used in the study. The literature review, definition of the purpose of the case study, and early determination of the potential audience for the final report guide how the study will be designed, conducted, and publicly reported.

- Step 2. Select the cases and determine data gathering and analysis techniques

During the design phase of case study research, the researcher determines what approaches to use in selecting single or multiple real-life cases to examine in depth and which instruments and data gathering approaches to use. A key strength of the case study method involves using multiple sources and techniques in the data gathering process. The researcher determines in advance what evidence to gather and what analysis techniques to use with the data to answer the research questions. Data gathered is normally largely qualitative, but it may also be quantitative. Tools to collect data can include surveys, interviews, documentation review, observation, and even the collection of physical artifacts. The researcher must use the designated data gathering tools systematically and properly in collecting the evidence. Throughout the design phase, researchers must ensure that the study is well constructed to ensure construct validity and reliability.

- Step 3. Prepare to collect the data

Because case study research generates a large amount of data from multiple sources, systematic organization of the data is important to prevent the researcher from becoming overwhelmed by the amount of data and to prevent the researcher from losing sight of the original research purpose and questions. The researchers must have the basic concepts of the study, terminology, processes, and methods, and how to properly apply the techniques being used in the study and to understand how the gathering of data using multiple techniques strengthens the study by providing opportunities for triangulation during the analysis phase of the study. Good researchers review documents looking for facts, but also read between the lines and pursue collaborative evidence elsewhere when that seems appropriate. Researchers need to understand the purpose of the study and grasp the issues and must be open to contrary findings. Investigators must also be aware that they are going into the world of real human beings who may be threatened or unsure of what the case study will bring. Researchers need to anticipate key problems and events, identify key people, prepare letters of introduction, establish rules for confidentiality, and actively seek opportunities to revisit and revise the research design in order to address and add to the original set of research questions.

- Step 4. Collect data in the field

Researchers carefully observe the object of the case study and identify causal factors associated with the observed phenomenon. Renegotiation of arrangements with the objects of the study or addition of questions to interviews may be necessary as the study progresses. Case study research is flexible, but when changes are made, they are documented systematically. Field notes record feelings and intuitive hunches, pose questions, and document the work in progress. Field notes should be kept separate from the data being collected and stored for analysis. The researcher may enter some data into a database and physically store other data, but the researcher documents, classifies, and cross-references all evidence so that it can be efficiently recalled for sorting and examination over the course of the study.

- Step 5. Evaluate and analyze the data

The researcher examines raw data using many interpretations in order to find linkages between the research object and the outcomes with reference to the original research questions. Throughout the evaluation and analysis process, the researcher remains open to new opportunities and insights. The case study method, with its use of multiple data collection methods and analysis techniques, provides researchers with opportunities to triangulate data in order to strengthen the research findings and conclusions.

The tactics used in analysis force researchers to move beyond initial impressions to improve the likelihood of accurate and reliable findings. Researchers categorize, tabulate, and recombine data to address the initial propositions or purpose of the study, and conduct cross-checks of facts and discrepancies in accounts. Focused, short, repeat interviews may be necessary to gather additional data to verify key observations or check a fact. Specific techniques include placing information into arrays, creating matrices of categories, creating flow charts or other displays, and tabulating frequency of events. Researchers use the quantitative data that has been collected to corroborate and support the qualitative data which is most useful for understanding the rationale or theory underlying relationships.

- Step 6. Prepare the report

Exemplary case studies report the data in a way that transforms a complex issue into one that can be understood, allowing the reader to question and examine the study and reach an understanding independent of the researcher. The goal of the written report is to portray a complex problem in a way that conveys a vicarious experience to the reader. Case studies present data in very publicly accessible ways and may lead the reader to apply the experience in his or her own real-life situation. Researchers pay particular attention to displaying sufficient evidence to gain the readers confidence that all avenues have been explored, clearly communicating the boundaries of the cases and giving special attention to conflicting propositions.

Techniques for composing the report can include handling each case as a separate chapter or treating the case as a chronological recounting. Some researchers report the case study as a story. During the report preparation process, researchers critically examine the document looking for ways the report is incomplete.

Conclusion:

Case studies are complex because they generally involve multiple sources of data, may include multiple cases within a study, and produce large amounts of data for analysis. Researchers from many disciplines use the case study method to build upon theory, to produce new theory, to dispute or challenge theory, to explain a situation, to provide a basis to apply solutions to situations, to explore, or to describe an object or phenomenon. The advantages of the case study method are its applicability to real-life, contemporary, human situations and its public accessibility through written reports. Case study results relate directly to the common reader's everyday experience and facilitate an understanding of complex real-life situations [20].

3.5. Developing A Case Study

Many well-known case study researchers such as Robert E. Stake, Helen Simons, and Robert K. Yin have written about case study research and suggested techniques for organizing and conducting the research successfully. This introduction to case study research draws upon their work and proposes six steps that should be used:

- Determine and define the research questions,
- Select the cases and determine data gathering and analysis techniques,
- Prepare to collect the data,
- Collect data in the field,
- Evaluate and analyze the data,
- Prepare the report,

Among these steps some of them which has been used are given next.

- Determination and definition of the research questions

This case study has been conducted on a ready–made garments manufacturing industry. It has been established the focus of the study by forming questions about the workmanship quality of garments related situation or problem to be studied and determining a purpose for the study. It has been investigated the object of the case study in depth using the research questions. Case study research generally answers one or more questions which begin with "how" or "why." Questions of this study were targeted to a limited number of events or conditions and their interrelationships.

To make questions important considerations of the research:

- ❖ Company profile,
- ❖ Production capacity,
- ❖ Land area,
- ❖ Manpower,
- ❖ Present quality level of garments,
- ❖ Quality measuring parameter,
- ❖ Present DHU level of the factory,
- ❖ Major quality defects,
- ❖ Nature of defects and frequency of defects,
- ❖ Manpower engaged in quality controlling,

- Selection of the cases and determination of data gathering techniques

Existing quality controlling system has been chosen to examine and direct interview has been taken and data from the real field has been collected.

- Data collection in the field

Data has been collected from different sources at different time form the chosen company. From top management, information about the company and its products has been taken. Workmanship quality level of sewing process of garments has been chosen for this case study. Data regarding quality level and defects in sewing process of garments manufacturing have been taken from real field of sewing production floor of the company. Form its 6 production floor (unit) having altogether 65 lines, 6 lines from 6 production floor (unit) have been chosen.

Selected lines are: Unit-1: line-1; Unit-line-2: 6; Unit-line-3: 5; Unit-4: line-9; Unit-5: line-1; and Unit-6: line-1

- Evaluation and Analyze the Data

It is examined the raw data using many interpretations in order to find linkages between the research object and the outcomes with reference to the original research questions. To analyze the data, DMAIC and cause-effect diagram have been used for analysis.

- Prepare the report

Then report have been prepared systematically by close supervision.

3.6. Outline of Methodology/ Experimental Design

The methodology of this research work is a case study research. This case study is conducted in a selected garments company located in Gazipur, Bangladesh. The study gives an idea about the existing scenario of the quality level of sewing section of the garments company. However, this study is aimed to improve the sewing quality level.

3.7. Developing Case Study by Applying DMAIC Methodology

Define phase:

Most successful and promising industrial sector of Bangladesh is the garments manufacturing industries. As the days goes, local and global competition is increasing rapidly. The major challenges are costs and quality of products (garments) manufacturing. Quality is directly related to costs. Achieving desired workmanship quality of sewing processes of garments is the most challenging and it is a competitive advantage in garments manufacturing industries of Bangladesh. This research paper address the various non-conformity or defects in sewing processes of garments manufacturing. The goal of this research paper to identify and reduce or eliminate defects in sewing processes of garments manufacturing industries. Most frequent defects have been selected based on their priority and analyzed for their root causes to solve them.

Measure Phase:

The quantified parameters are:

Defect rate (DHU) in garments production in sewing section in term of percentage.

Efficiency of production line hourly, daily monthly basis expressed in percentage.

Cost benefits in BDT

The relevant data have been collected by both a set of questionnaires and from real field observation and these data have been measured by defined calculation.

Analyze Phase:

This phase is very important of DMAIC approach. Identified and selected data of defects of sewing processes are analyzed based on their frequency, priority. These data are analyzed to find out their causes and to seek improvement opportunities

Improve Phase:

In this phase, solutions have been developed of defects happening in swinging processes of garments manufacturing. And these developed solutions have been applied to solve the targeted problem of defects as a pilot run for improvement.

Control Phase:

In this phase, improvement against implemented solutions have been monitored and recorded in a planned time interval. Some gaps are identified and some modification has been done for sustainable result.

CHAPTER FOUR

COMPANY OVERVIEW & DATA COLLECTION

4.1. Introduction

This chapter presents the company profile in a brief and some relevant findings from the company in which the case study has been conducted. The case study has been conducted in a knit garments manufacturing company. Based on the questionnaire discussed in chapter three the study has been performed. The findings are presented.

4.2. Company Overview

Location: Gazipur.

Total Land Area: Total land area 8.25 acres & using area 7 acres.

Total sewing Floor: 6

Total sewing Lines: 65

Total manpower: 4560

Manpower in garments section: 3940.

Monthly cutting capacity: 2.5 million pieces of garments.

Monthly knitting capacity: 300 tons of fabrics.

Monthly dyeing capacity: 650 tons of fabrics.

Present efficiency level: 56%

Present DHU of factory: 14.5%

Monthly production capacity: 2.4 million pieces of garments.

Monthly export value: 5.5 Million Dollars.

Products: Ready-Made Garments (Knit Garment Items) such as T-shirt, Polo Shirt, Sweat Shirt, Night Pajama, Shorts, Leggings, Tank top, Hoody-Jacket etc.

Major buyers: The major buyers are H & M, C & A US Polo, NKD and Mango.

4.3. Quality Control System

The selected company start its quality control system from incoming yarn quality to exporting garments. As this case focuses on the workmanship quality improvement of sewing processes in sewing production of this factory, so quality control system of sewing section which the company is following has been presented here.

The quality control system of this company for sewing production section has been presented below in terms of flow chart. Although the following flow chart of quality control of sewing production start from accessories inspection and then fabrics inspection but actually it starts from inline process quality control and ends with end line quality inspection of complete garments. Other pre and post steps are associate to complete the total quality control system.

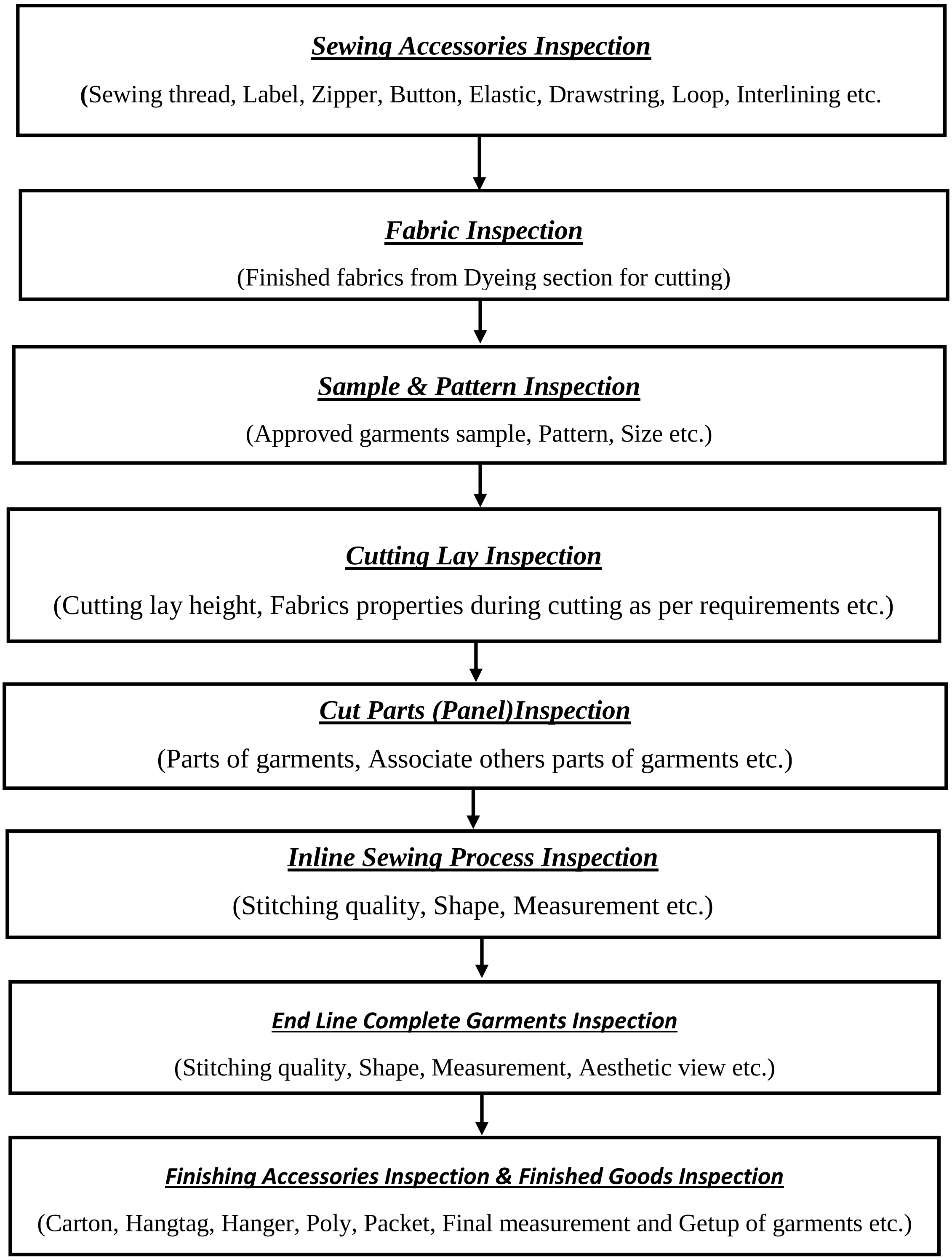

Figure 4.1: Flow chart of quality control of sewing process.

4.4. Basic Standard Organogram of Quality Department the Selected Company

The selected company has its own organogram of quality control department in a hierarchy like the figure given below. In the organogram, the number in first bracket indicates the number of persons in the respective position and number in second bracket indicates the number of production floor.

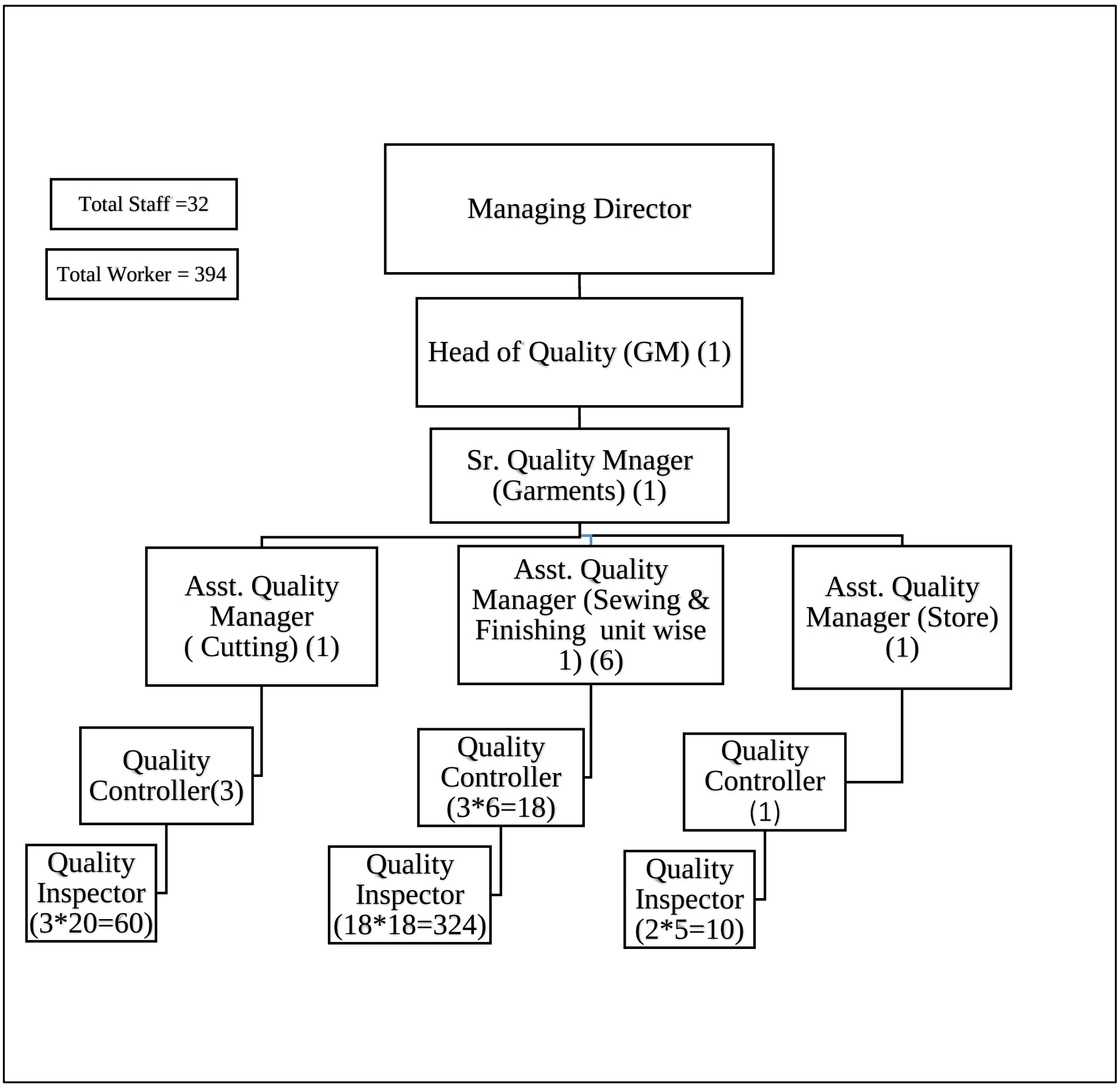

Figure 4.2: Basic organogram of quality control department.

4.5. Defects Identification

There are many defects in sewing processes in garments manufacturing industries with respect to the standard requirements of buyers. Most of the defects are related to workmanship of the operator of the sewing machines. Approximately more than 50 types of defects usually are found in RMG industries. A list of the major defects which most frequently occur, has been identified in the selected factory and is shown in table 4.1.

Table 4.1: List of major defects.

Serial No.	Defect Name
1	Broken Stitch
2	Waviness
3	Needle Mark
4	Unsecured Security Tack
5	Uneven Hem
6	Joint stich
7	Measurement Deviation
8	Open seam
9	Uneven Gathering
10	Puckering
11	Pleat
12	Raw edge
13	Slanted
14	Oil Spot
15	Shading
16	Wrong Sewing Thread Used
17	Wrong Stitch per Inch (SPI)
18	Uneven Sleeve or Leg length
19	Point Up-down
20	Un-cut thread
21	Lose Thread
22	Loose Stitch
23	Twisting
24	Uneven Neck Width
25	Skip Stitch
26	Dirty Spot
27	Down/Un-even Stitch
28	Wrong Label Position
29	Scissor Cut
30	Label Mistake
31	Size Mistake
32	Label Missing
33	Security Tack Missing
34	Button Missing
35	Bow Missing

4.6. Data Collection

Relevant data have been collected from the 6 selected production lines of 6 different production floor or unit. The selected lines are line 1 from production floor 1, line 6 from production floor 2, line 5 from production floor 3, line 9 from production floor 4, line 1 from production floor 5, line 1 from production floor 6. The selected lines have been denoted in some case in this research paper as U1L1, U2L6, U3L5, U4L9, U5L1, U6L1, respectively. Raw data have been collected as defect name wise and for the month of November-2019, December-2019 and January-2019 and their summary of data before the analysis of the data and show in the appendices. Relevant data after the analysis and implementation of the month February-2019 have collected and also shown in appendices.

CHAPTER 5

ANALYSIS & RESULT

5.1. Defect Identification & Selection for Analysis

Data have been collected against the selected production lines of sewing section of 3 consecutive months of November, December in 2018 and January in 2019 for analysis the problem on various defects in sewing processes.

Table-5.1: List of defects and their 3-month data summary of the selected lines.

Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	769630	9816	1.28%
2	Waviness		1348	0.18%
3	Needle Mark		850	0.11%
4	Unsecured Security Tack		940	0.12%
5	Uneven Hem		888	0.12%
6	Joint stich		4697	0.61%
7	Measurement Deviation		1468	0.19%
8	Open seam		4049	0.53%
9	Uneven Gathering		1113	0.14%
10	Puckering		3425	0.45%
11	Pleat		1251	0.16%
12	Raw edge		5111	0.66%
13	Slanted		987	0.13%
14	Oil Spot		11799	1.53%
15	Shading		13711	1.78%
16	Wrong Sewing Thread Used		742	0.10%
17	Wrong Stitch per Inch (SPI)		2348	0.31%
18	Uneven Sleeve / Leg length		1138	0.15%
19	Point Up-down		6255	0.81%
20	Un-cut thread		28553	3.71%
21	Lose Thread		7045	0.92%
22	Loose Stitch		1367	0.18%
23	Twisting		1864	0.24%
24	Uneven Neck Width		1110	0.14%
25	Skip Stitch		8250	1.07%
26	Dirty Spot		5643	0.73%
27	Down/Un-even Stitch		967	0.13%
28	Wrong Label Position		680	0.09%

Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
29	Scissor Cut	769630	395	0.05%
30	Label Mistake		1016	0.13%
31	Size Mistake		2847	0.37%
32	Label Missing		787	0.10%
33	Security Tack Missing		381	0.05%
34	Button Missing		98	0.01%
35	Bow Missing		80	0.01%
Total			133019	17.28%

5.1.1. Frequency diagram of defects

Based on the category wise data collection of defects for 3 consecutive months, the following graphical diagram is drawn for total defects.

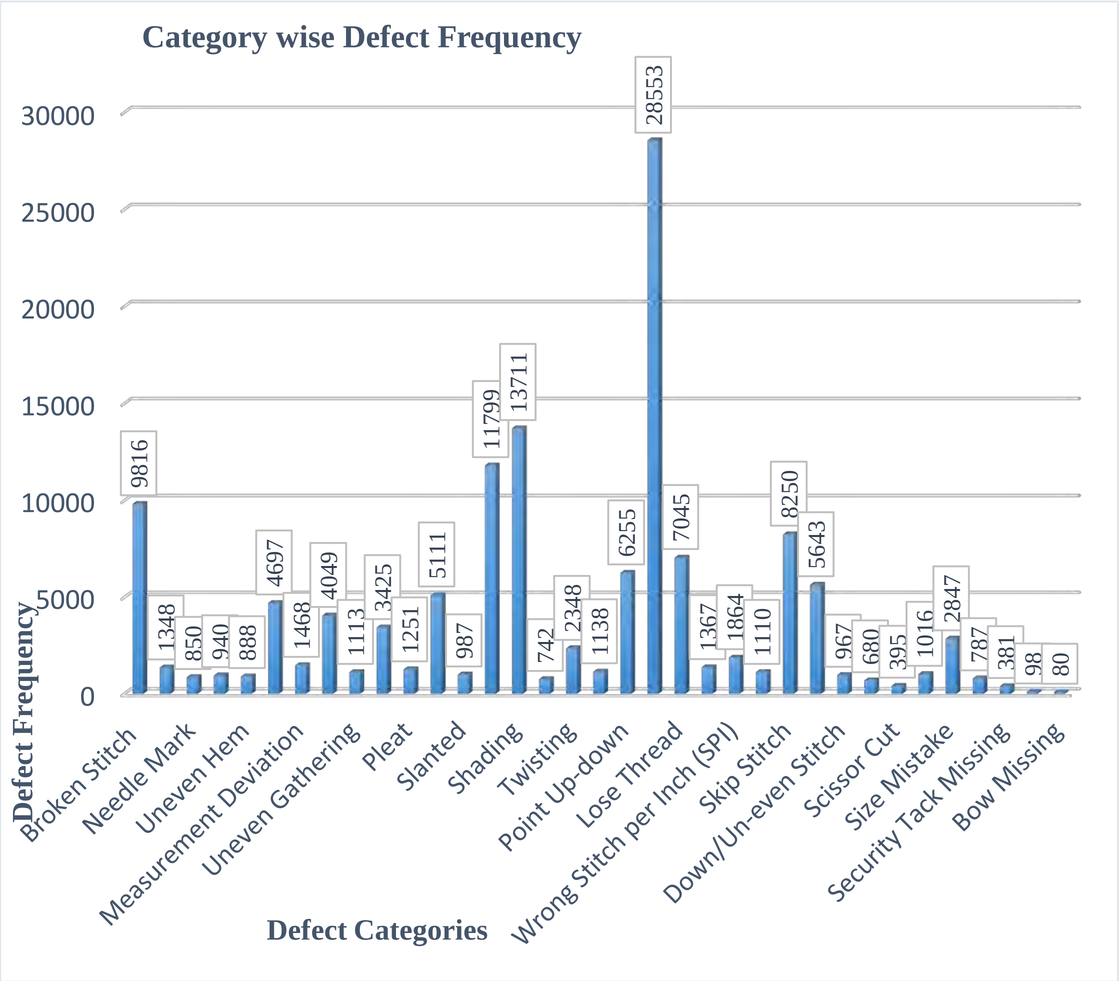

Figure 5.1: Frequency diagram of major sewing defects.

5.1.2. Defect priority list by Pareto chart diagram

Based on the 3-month data summary a Pareto Analysis Chart diagram has been drawn to select most frequent 1st 14 defect to find out the root causes by Fish-bone diagram and to develop solutions to reduce or eliminate them.

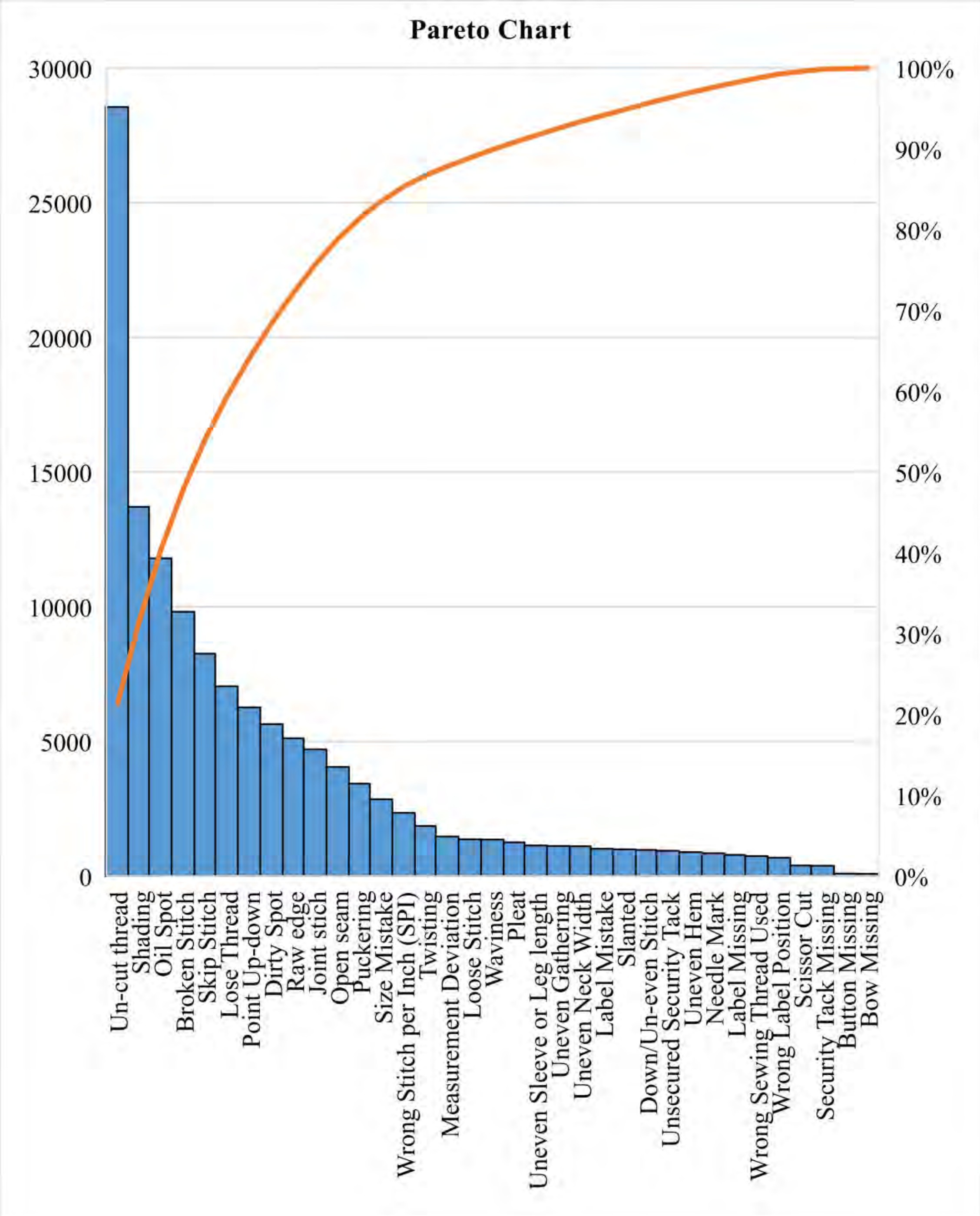

Figure 5.2: A Pareto Chart for selecting defects for analysis based on priority of frequency.

5.1.3. Selecting first 14 defects for analyzing

Based on the frequency and Pareto chart analysis, 1st 14 defects have been chosen for analysis which will represent the complete study. The list of 1st 14 selected defects are given below:

Table 5.2: List of defects chosen for root cause analysis.

First 14 defects based on priority of frequency	
Serial No.	Defect Name
1	Un-cut thread
2	Shading
3	Oil Spot
4	Broken Stitch
5	Skip Stitch
6	Lose Thread
7	Point Up-down
8	Dirty Spot
9	Raw edge
10	Joint stich
11	Open seam
12	Puckering
13	Size Mistake
14	Wrong Stitch per Inch (SPI)

5.2. Root Cause Analysis by Cause and effect or Fishbone Diagram

Cause-effect or Fish-bone diagram is drawn below for the first 14 defects on priority list to identify the possible root causes and possible solutions to reduce or eliminate them and the possible solutions of each root cause of these defects are developed as below.

Defect 1: Un-cut Thread

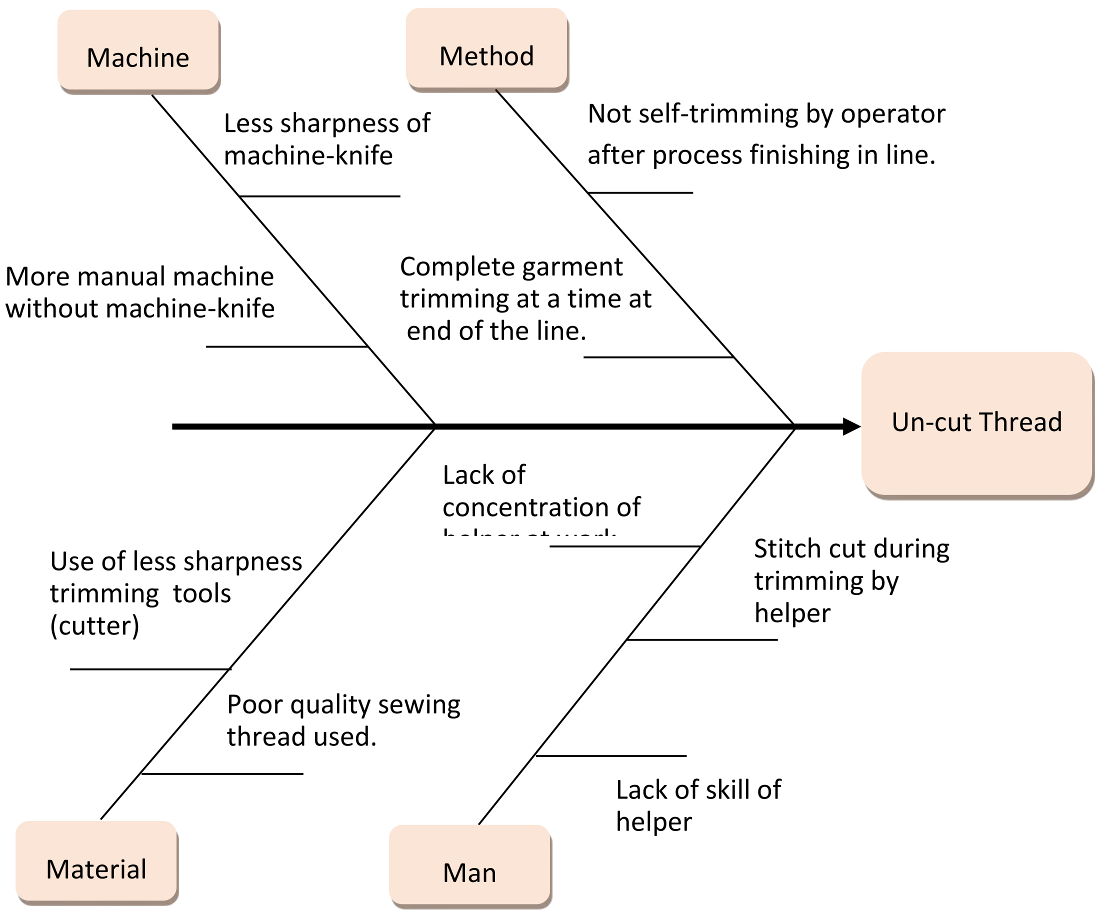

Figure 5.3: Fish-bone diagram for Un-cut Thread.

Developed Solutions:

Defect Name	Causes	Solutions
Un-cut Thread	Bluntness of machine-knife and trimming tools.	Sharpe trimming tools and machine-knife were used.
	Lack of concentration and skill.	Counselling & motivation programs were done and skill development training were given.
	Poor quality sewing thread.	Right quality sewing threads were used
	Cutting knife less manual machine used.	Auto thread trimming machines were used in the selected lines.
	Complete trimming at end of line.	Process wise self-trimming by operator in line trimming were practiced.

Defect 2: Shading

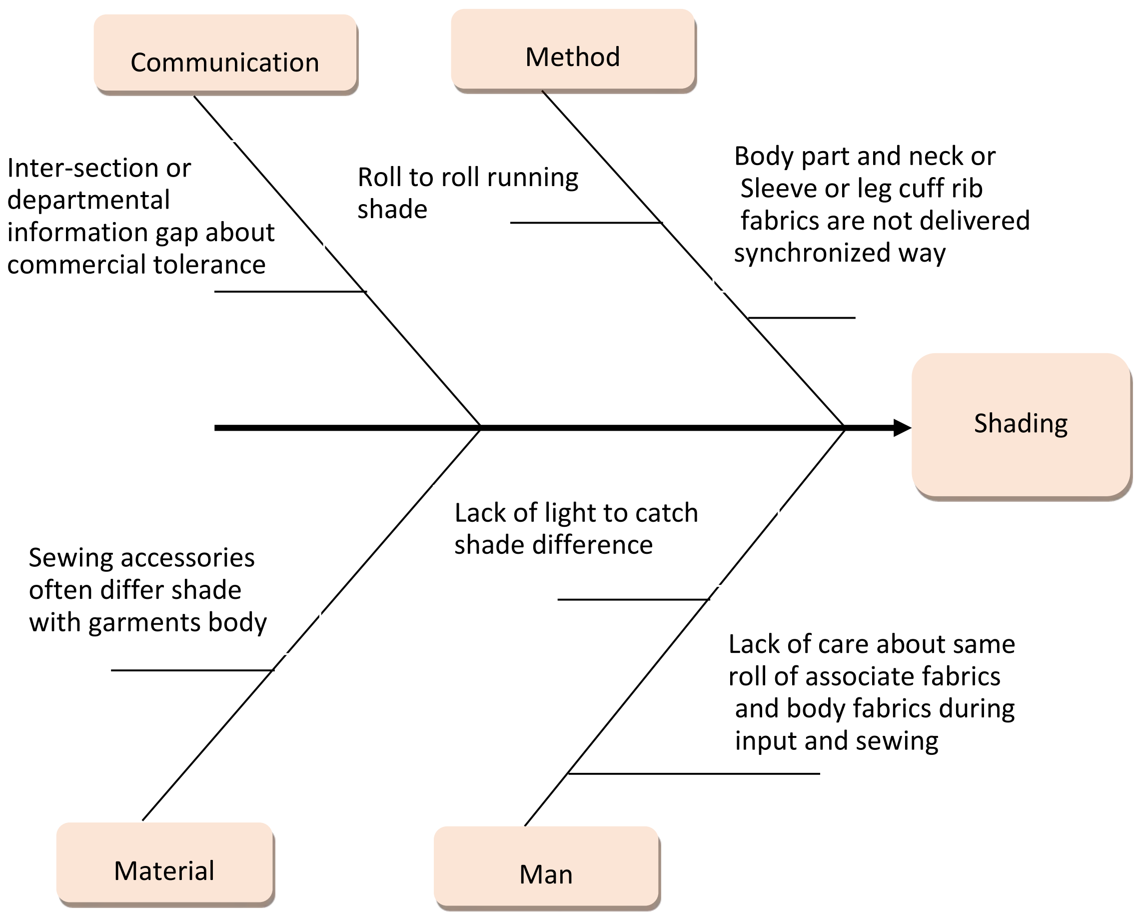

Figure 5.4: Fish-bone diagram for Shading.

Developed Solutions:

Defect Name	Causes	Solutions
Shading	Running shade of fabrics and accessories shade.	Quality policy was updated and more check points established to control shade of fabrics and accessories.
	Discrete input of parts.	All parts of a garments are given delivery as input as a package.
	Lack of light	Light flux was increased in shade checking area.
	Communication gaping.	Proper authority has been design for special tolerance regarding shade issue.

Defect 3: Oil Spot

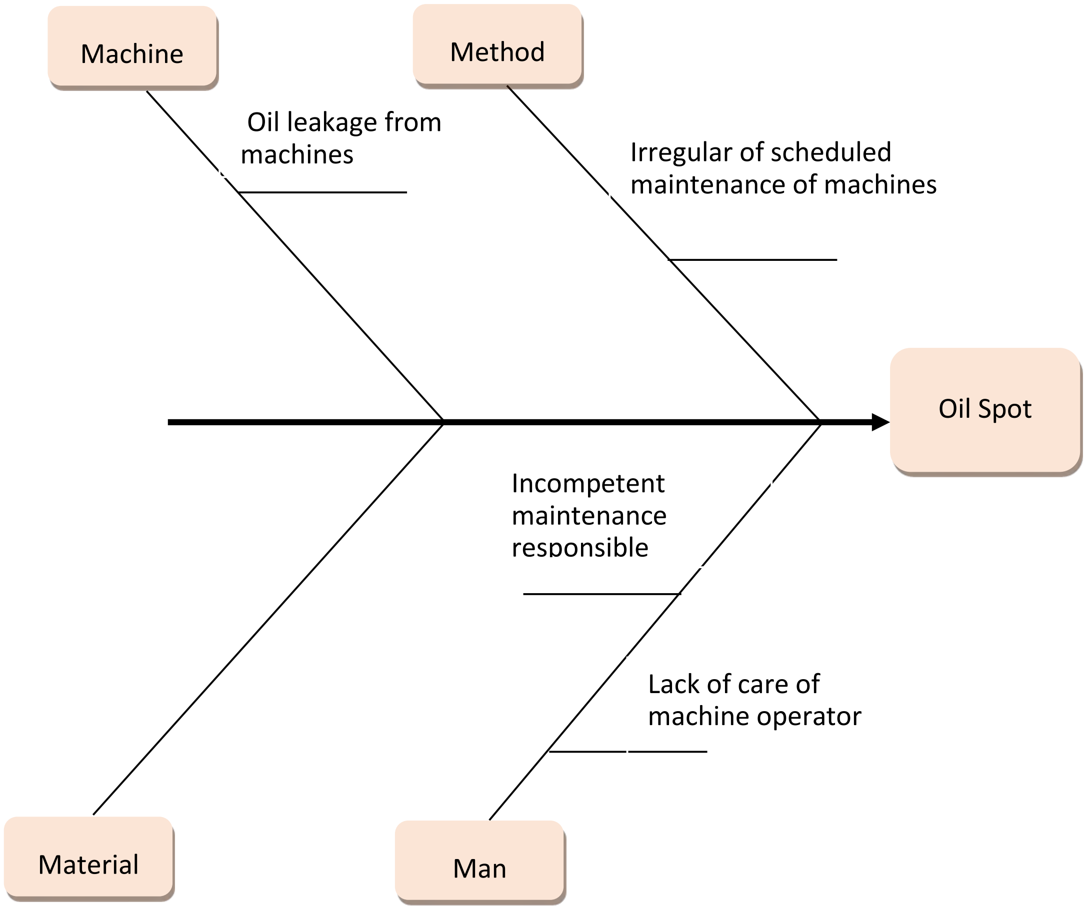

Figure 5.5: Fish-bone diagram for Oil Spot.

Developed Solutions:

Defect Name	Causes	Solutions
Oil Spot	Irregular scheduled maintenance.	Weekly scheduled program was regularized.
	Incompetency of maintenance responsible	Competence person was employed and skill development program was conducted.
	Lack of care of machine operator.	Counselling programs were done for operators about machine cleaning.

Defect 4: Broken Stitch

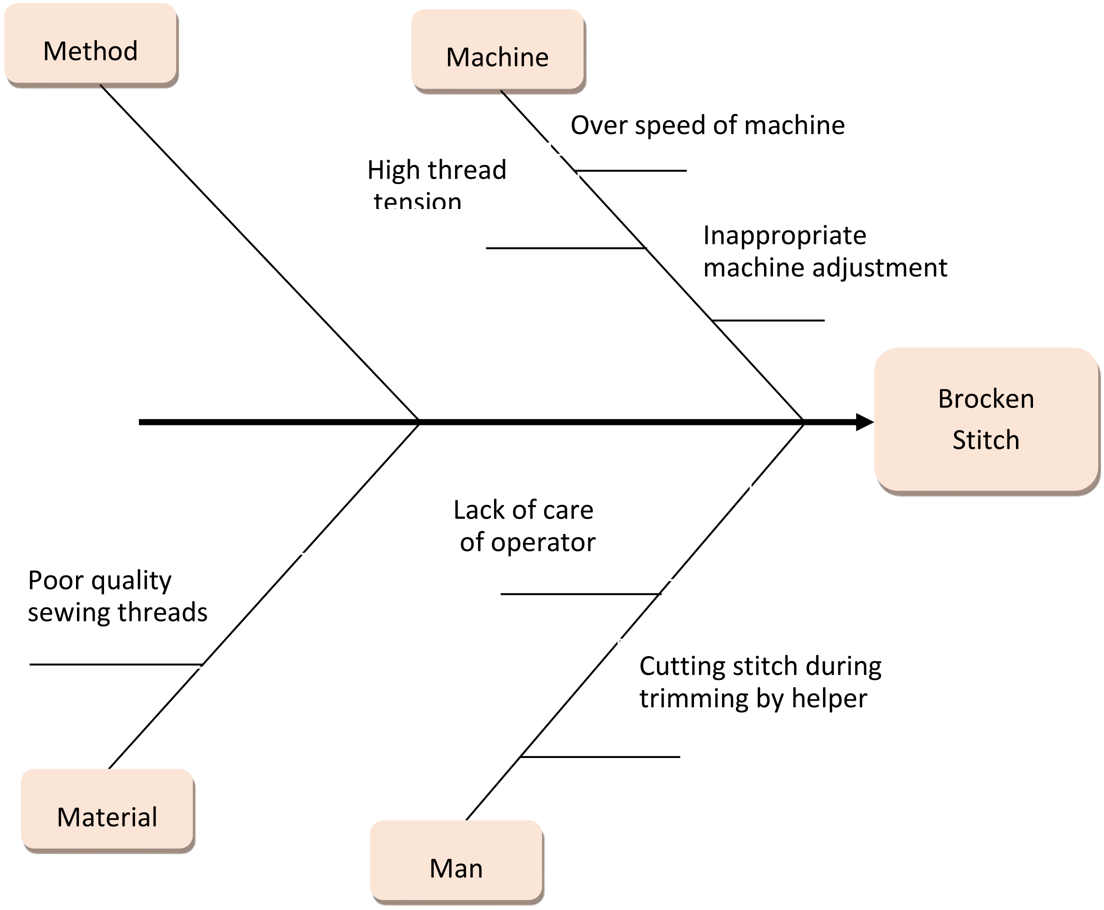

Figure 5.6: Fish-bone diagram for Broken Stitch.

Developed Solutions:

Defect Name	Causes	Solutions
Broken Stitch	Poor quality sewing threads used.	Right quality sewing threads were used.
	Improper thread tension and machine adjustment.	Appropriate adjustment was done on machine for appropriate thread tension and others.
	Lack of care of operator and helper.	Counselling programs were done for operators and helpers.

Defect 5: Skip Stitch

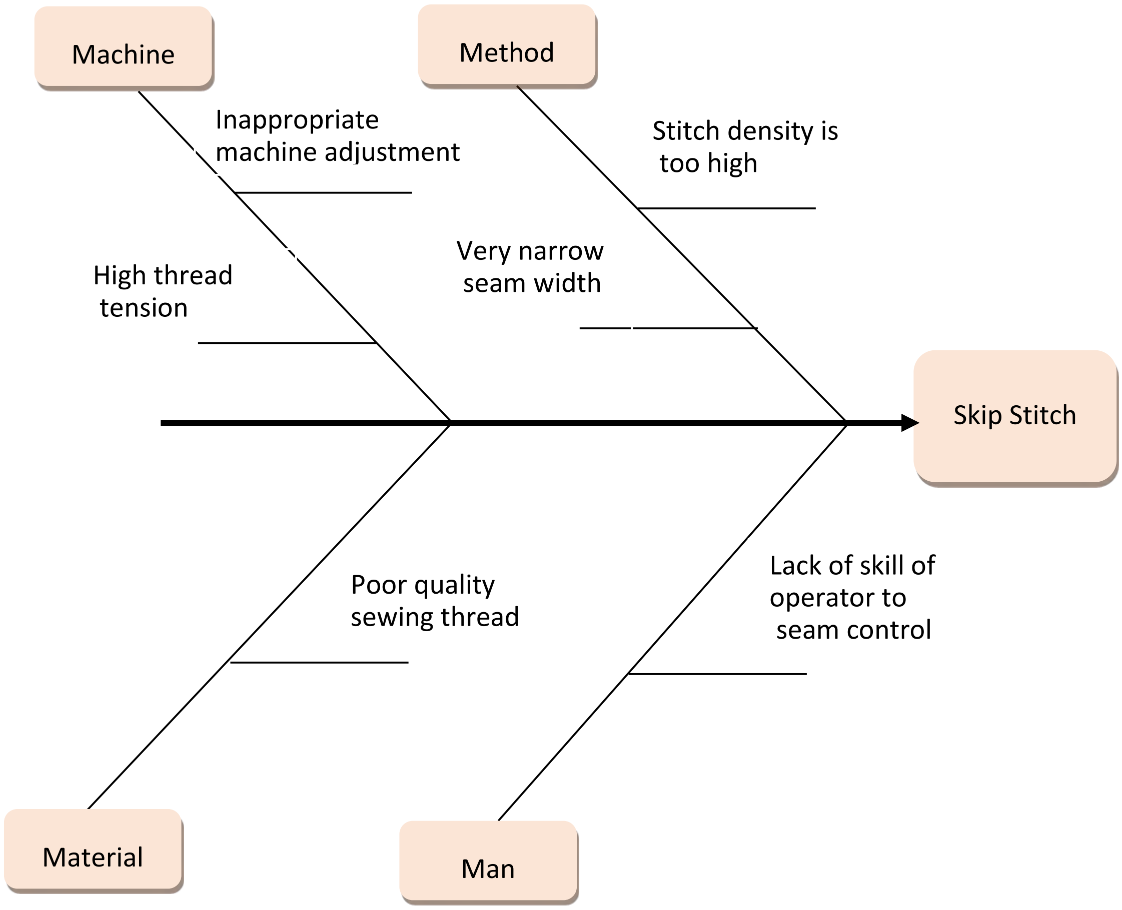

Figure 5.7: Fish-bone diagram for Skip Stitch.

Developed Solutions:

Defect Name	Causes	Solutions
Skip Stitch	Improper machine adjustment.	Appropriate adjustment was done on machine for appropriate thread tension and others.
	Poor quality sewing threads.	Right quality sewing threads were used.
	Improper seam and stitch density	Right stitch density and seam width as per fit for machine were adjusted.
	Lack of skill of operator to seam control.	Skill development training was given.

Defect 6: Loose Thread

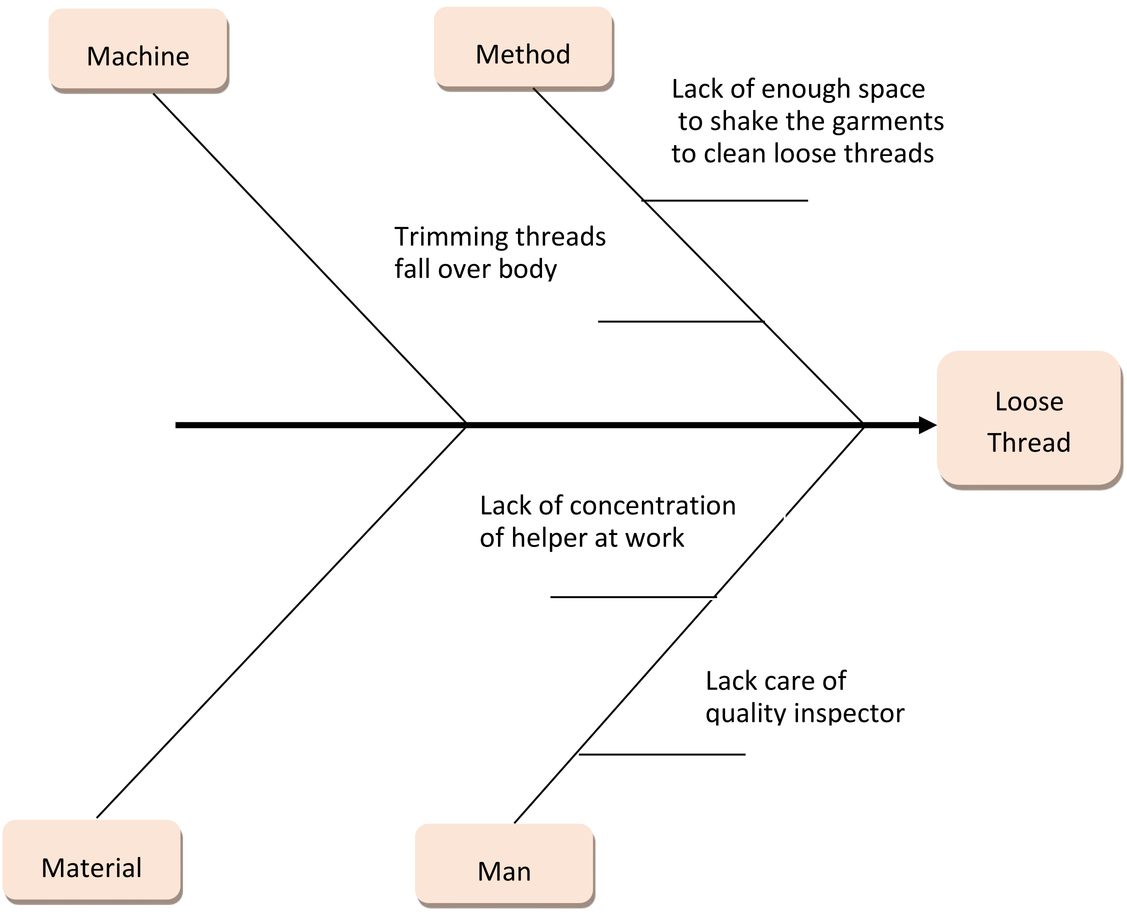

Figure 5.8: Fish-bone diagram for Loose Thread.

Developed Solutions:

Defect Name	Causes	Solutions
Loose Thread	Lack of concentration and care of helper and quality inspector.	Counselling & motivation programs were conducted.
	Trimming threads fall over body and lack of space.	Workstations were re-arranged.

Defect 7: Point Up-down

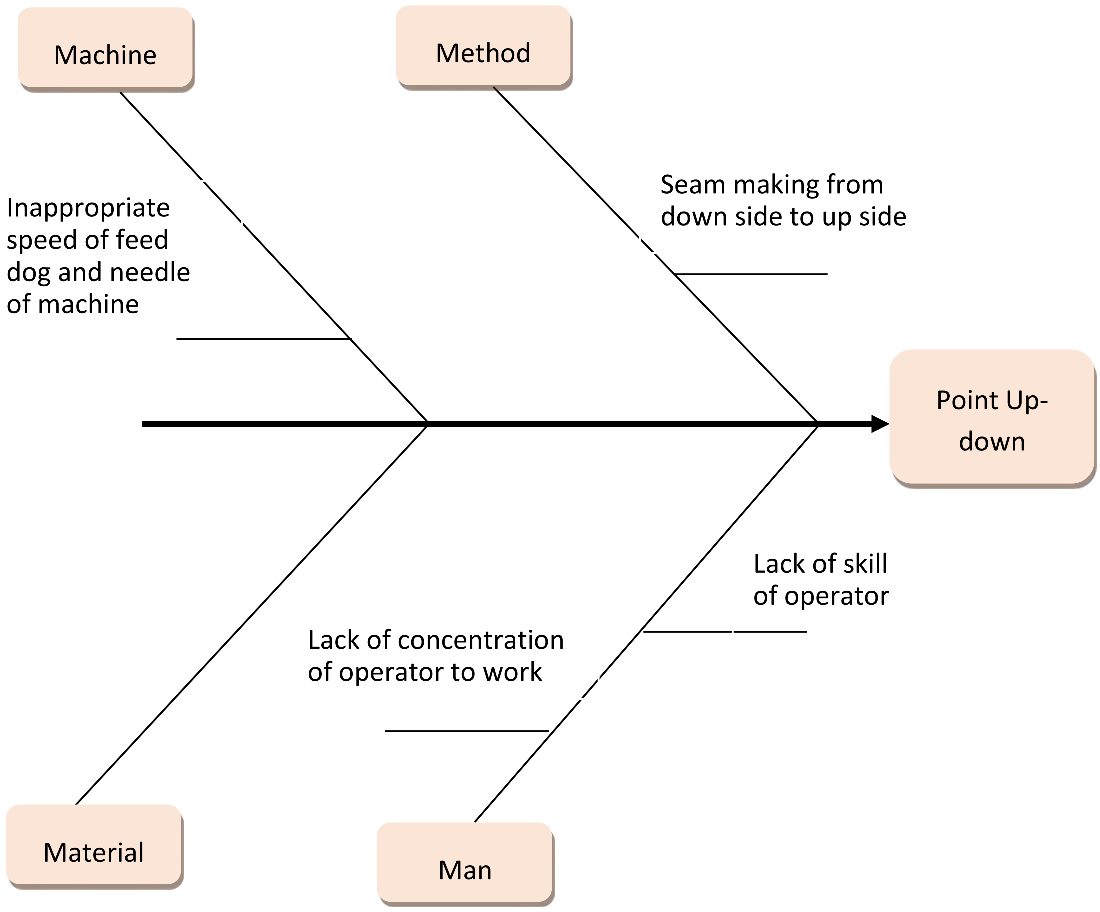

Figure 5.9: Fish-bone diagram for Point Up-down.

Developed Solutions:

Defect Name	Causes	Solutions
Point Up-down	Lack of skill of operator.	Skill development training was given.
	Lack of concentration of operator to work.	Counselling & motivation programs were done.
	Improper machine adjustment.	Appropriate adjustment was done on machine synchronized speed of feed dog and needle
	Wrong direction seam making.	Right direction of seam making were demonstrated

Defect 8: Dirty Spot

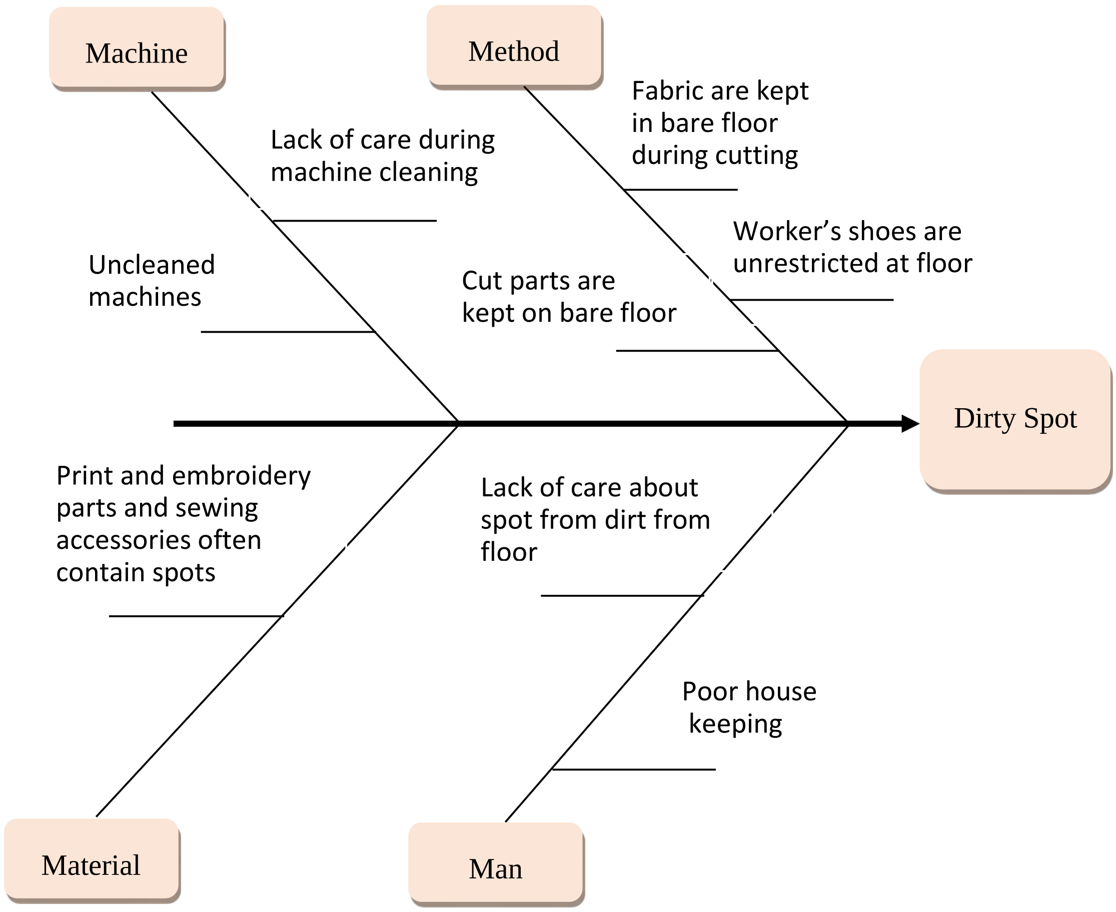

Figure 5.10: Fish-bone diagram for Dirty Spot.

Developed Solutions:

Defect Name	Causes	Solutions
Dirty Spot	Improper cleaning of floor and machine.	Awareness raising and counselling program were taken.
	Poor housekeeping floor keeping & dirty floor.	Pallet were used in cutting and sewing to keep fabrics and cut parts.
	Unrestricted shoes of workers.	Racks for shoes keeping were managed outside the floor to control shoes of workers.

Defect 9: Raw Edge

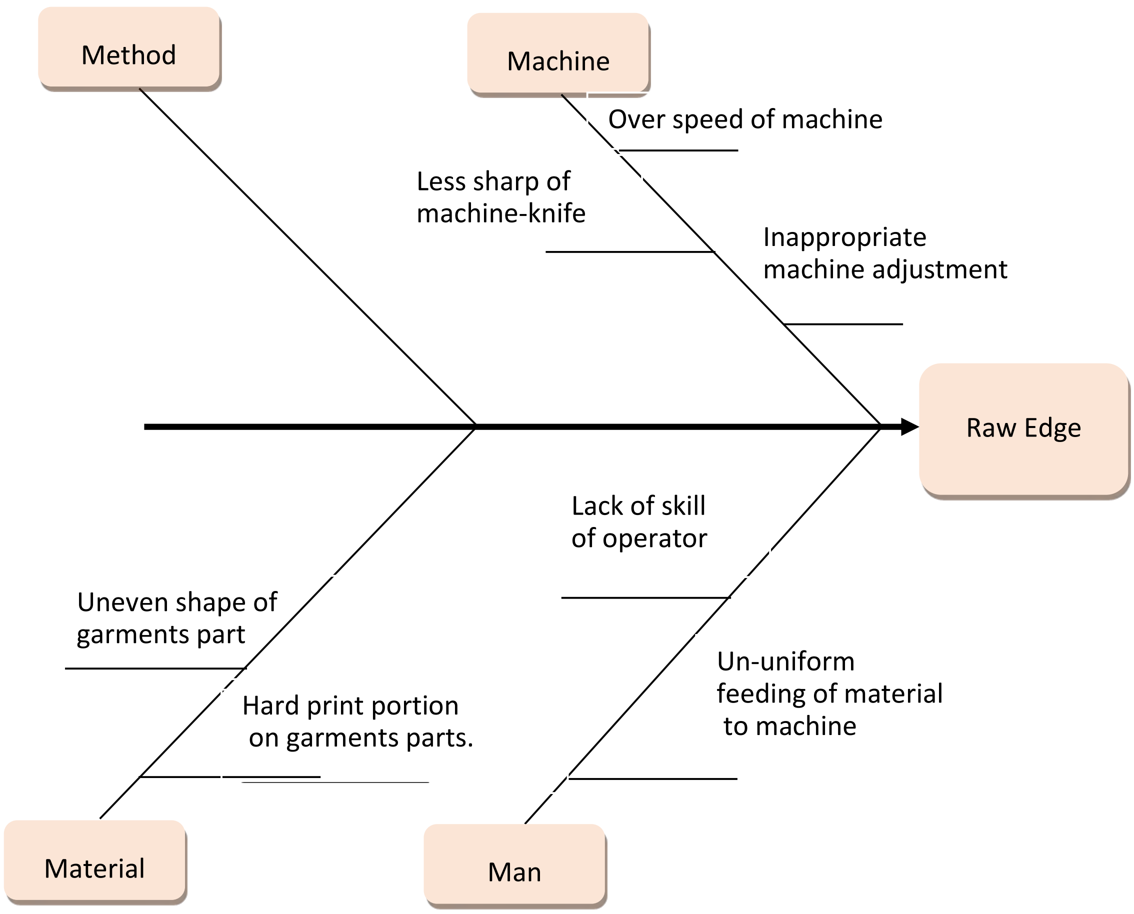

Figure 5.11: Fish-bone diagram for Raw Edge.

Developed Solutions:

Defect Name	Causes	Solutions
Raw Edge	Lack of skill or expertise.	Operator-skill development program was taken.
	Improper machine adjustment and sharp less cutting knife.	Appropriate adjustment was done on machine and sharp cutting knife was mounted.
	Uneven shape of garments parts and hard print portion.	Measures were taken in cutting section to cut garments part evenly.

Defect 10: Join Stitch

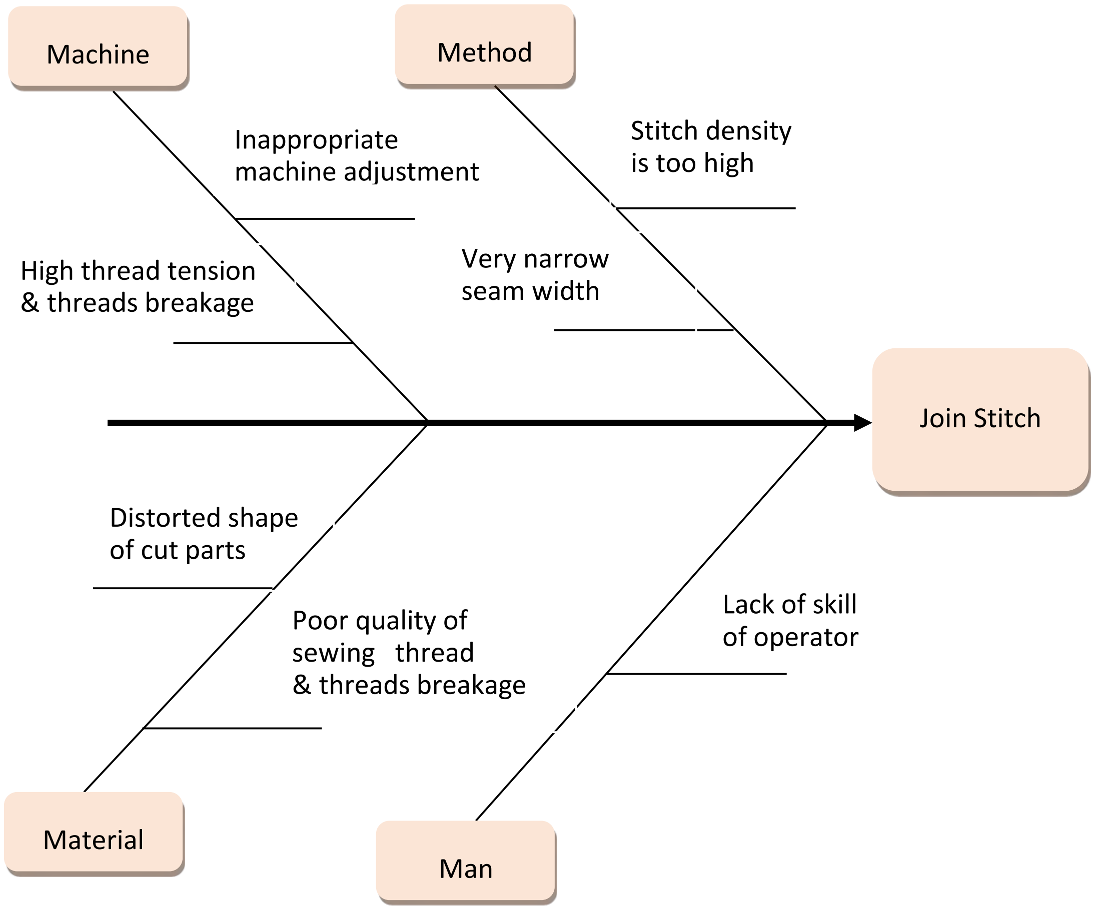

Figure 5.12: Fish-bone diagram for Join Stitch.

Developed Solutions:

Defect Name	Causes	Solutions
Join Stitch	Improper machine adjustment.	Appropriate adjustment was done on machine for appropriate thread tension and others.
	Poor quality sewing threads.	Right quality sewing threads were used.
	Improper seam and stitch density.	Right stitch density and seam width as per fit for machine were adjusted.
	Lack of skill operator	Skill development training was given.
	Distorted shape of cut parts.	Distorted cut parts were sorted out in cutting section and undelivered.

Defect 11: Open Seam

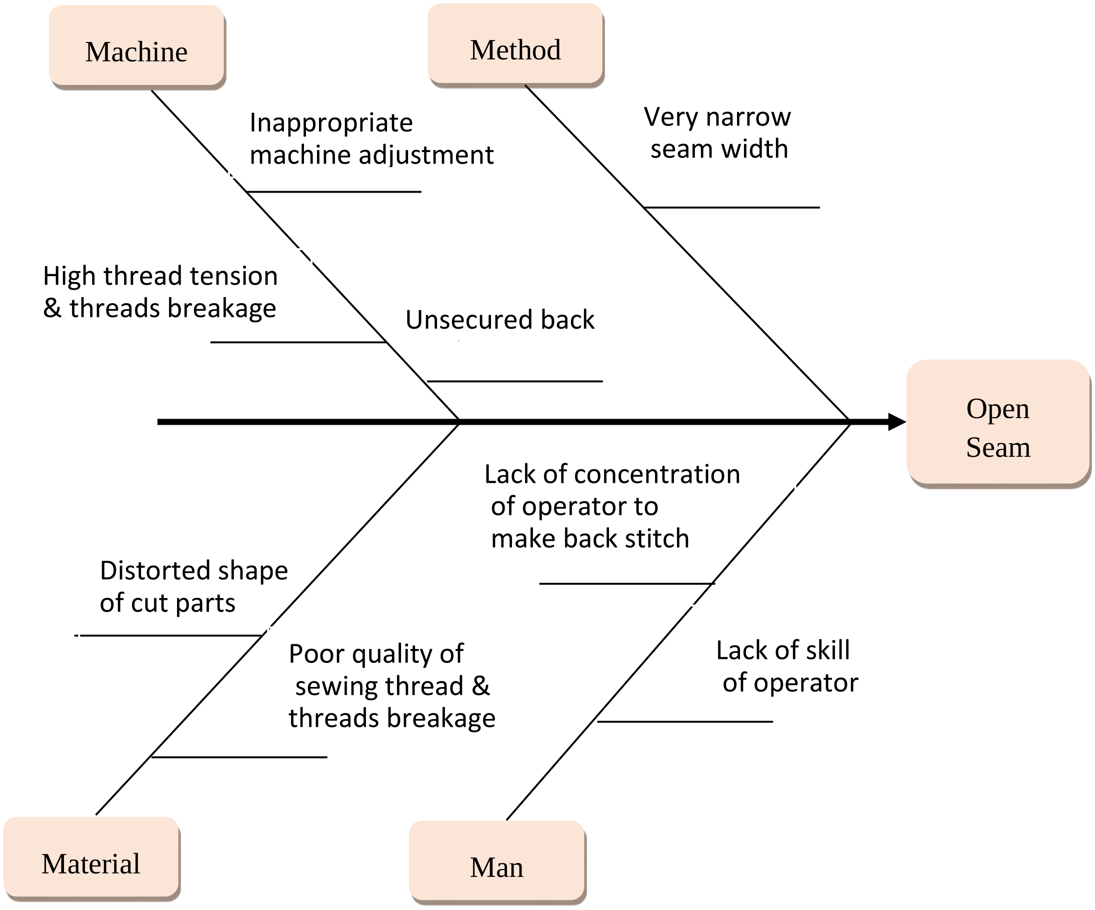

Figure 5.13: Fish-bone diagram for Open Seam.

Developed Solutions:

Defect Name	Causes	Solutions
Open Seam	Improper machine adjustment.	Appropriate adjustment was done on machine for appropriate thread tension , back stitch and others.
	Poor quality sewing threads.	Right quality sewing threads were used.
	Improper seam .	Right seam width as per fit for machine were adjusted.
	Lack of skill & concentration of operator.	Skill development training and motivation were given to operators.
	Distorted shape of cut parts	Distorted cut parts were sorted out in cutting section and undelivered.

Defect 12: Puckering

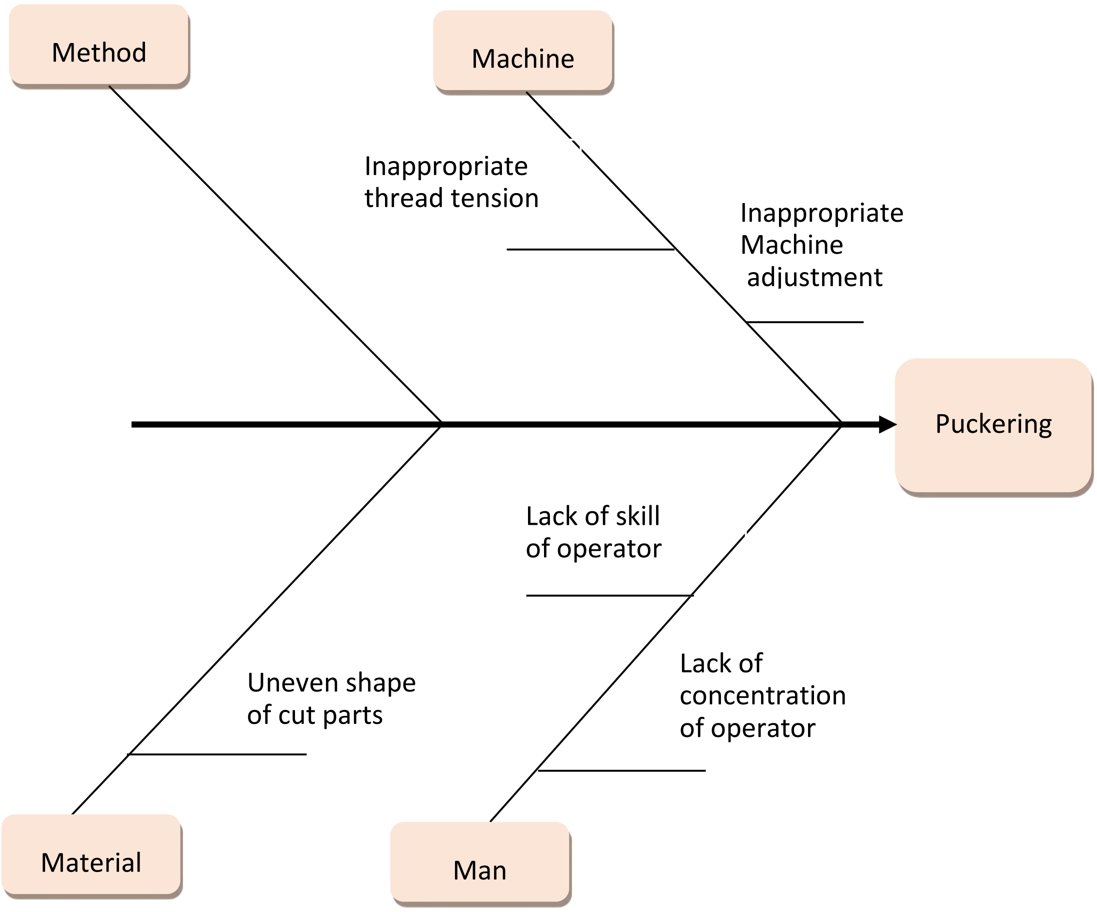

Figure-5.14: Fish-bone diagram for Puckering.

Developed Solutions:

Defect Name	Causes	Solutions
Puckering	Improper machine adjustment.	Appropriate adjustment was done on machine for appropriate thread tension , back stitch and others.
	Uneven Shape of cut parts.	Cutting instructions for proper shape of cut parts were demonstrated to cutting operators.
	Lack of skill & concentration of operator.	Skill development training and motivation were given to operators..

Defect 13: Size Mistake

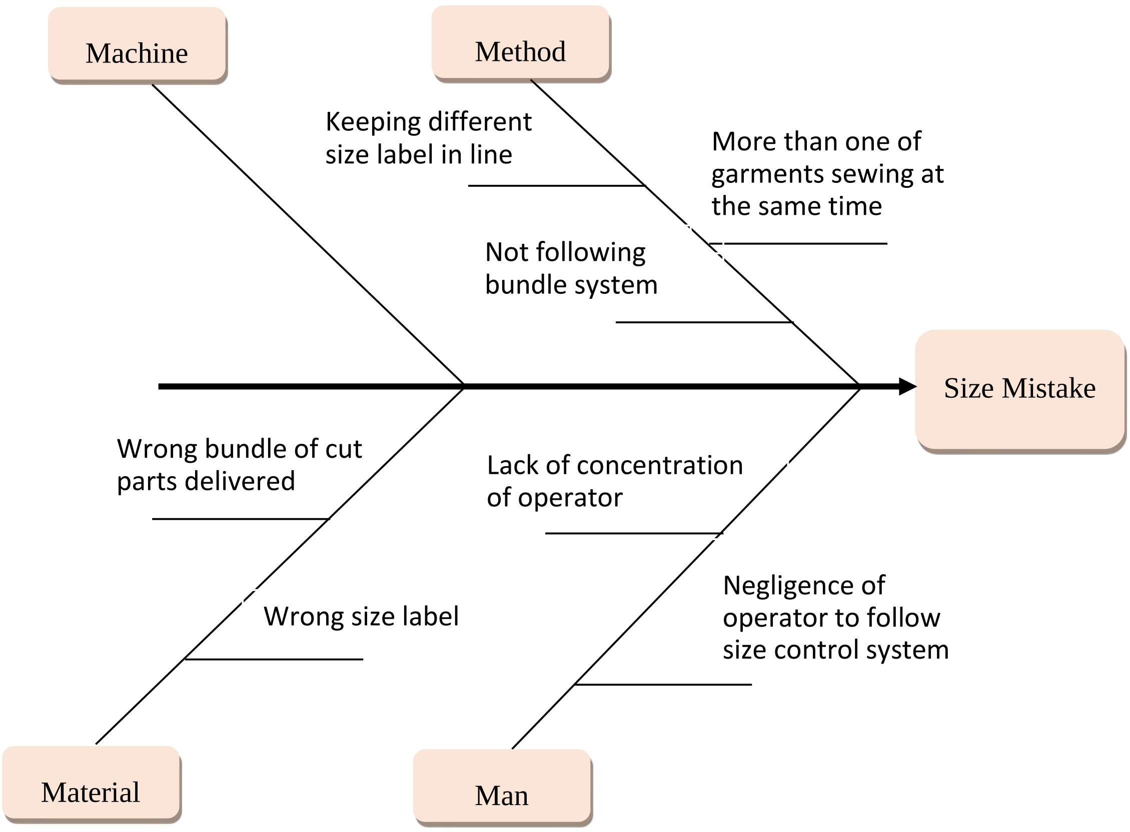

Figure 5.15: Fish-bone diagram for Size Mistake.

Developed Solutions:

Defect Name	Causes	Solutions
Size Mistake	Lack of concentration and negligence of operators.	Counselling & motivation programs were done.
	Size bundle system not following.	Counselling & motivation programs were done for maintain bundle system.
	Wrong label and bundle of cut parts.	Labels were checked by quality inspector in store and bundle of cut parts at cutting before delivery.
	Lack of skill & concentration of operator	Skill development training and motivation were given to operators..
	More than one size label and bundles of cut parts at line.	Singe size bundle and same size label were sewing at line at a time.

Defect 14: Wrong Stitch per Inch (SPI)

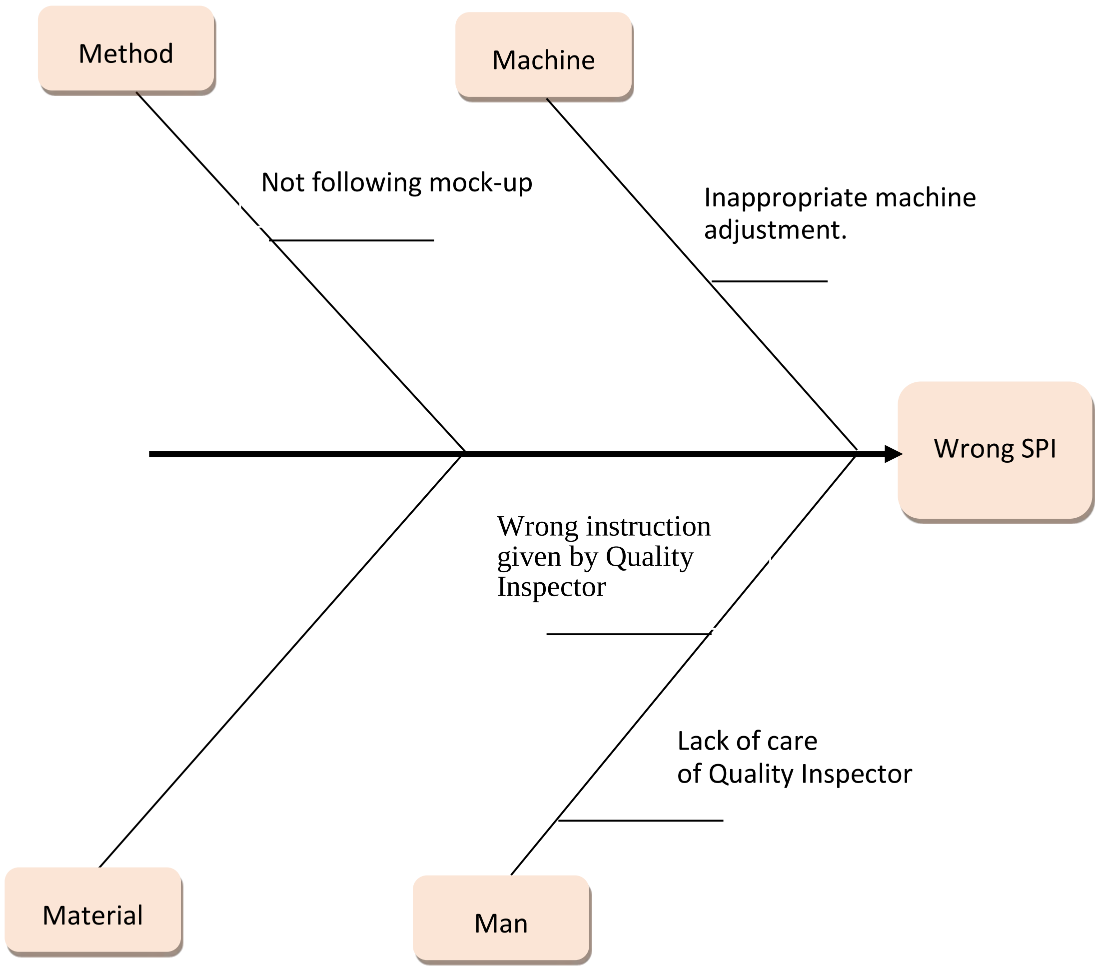

Figure 5.16: Fish-bone diagram for Wrong Stitch per Inch (SPI).

Developed Solutions:

Defect Name	Causes	Solutions
Wrong SPI	Lack of care & wrong instruction given by Quality Inspector. And mock-up not following by operator.	Counselling & motivation programs were done.
	Improper machine adjustment.	Appropriate adjustment was done on machine for appropriate for stitch density as per requirement

5.3. Training Program for Skill Development, Counselling and Motivation

According to the root causes analysis and findings, several programs on skill development and counselling and motivation programs were conducted. The training program summary are shown below:

Table 5.3: Summary of training program conducted.

Training Program						
Date	12 January-2019 to 24 January-2019					
Training Content	Participant	Number of Participant	Batch	Session	Days	Trainer
Skill development of Sewing Process	Sewing Operator	172	6	24	12	Sewing Technician
Counselling & Motivation	Sewing Operator, Sewing Helper, Quality Inspector and Sewing-Floor Staff	213	7	7	7	Production Manager, HR Manager and IE Manager.
Maintenance Skill development	Mechanics.	6	1	3	3	Mechanics Manager.
Supervision Skill Development	Supervisor / Line Chief.	12	1	1	1	Production Manager and IE Manager
Proper Cutting & Input Delivery	Supervisor/Line Chief, Input man, Quality Inspector, Sticker man..	74	3	3	3	Cutting Manager, IE Manager.
Total		477	18	38	26	

5.4. Implementation of Developed Solutions in the Selected Lines as a Pilot-run

The manpower who are closely related to the sewing production of the selected 6 lines were first trained to perform their job in the right method and skill according to the developed solutions. In these 6 lines sufficient auto trimming sewing machines were used to improve un-cut threads. Required machines with required parts, working tools and right quality material were used as the developed solutions. After the implementation of the developed solutions in the selected sewing production lines relevant data of defects were collected for the month of February-2019 to compare with the previous conditions. In the following table and graph, line wise production, inspected garments, defects and DHU of the month- February-2019 of the selected lines are presented.

Table 5.4: Line wise production and defects of Month-February-2019.

Production Unit / Floor	Selected Lines	February-2019		
		Inspected Garments	Defects	DHU (%)
1	1	43550	3453	7.93%
2	6	43500	3535	8.13%
3	5	43200	3591	8.31%
4	9	44030	3573	8.11%
5	1	43300	3398	7.85%
6	1	41970	3593	8.56%
Total /Average	6	259550	21143	8.15%

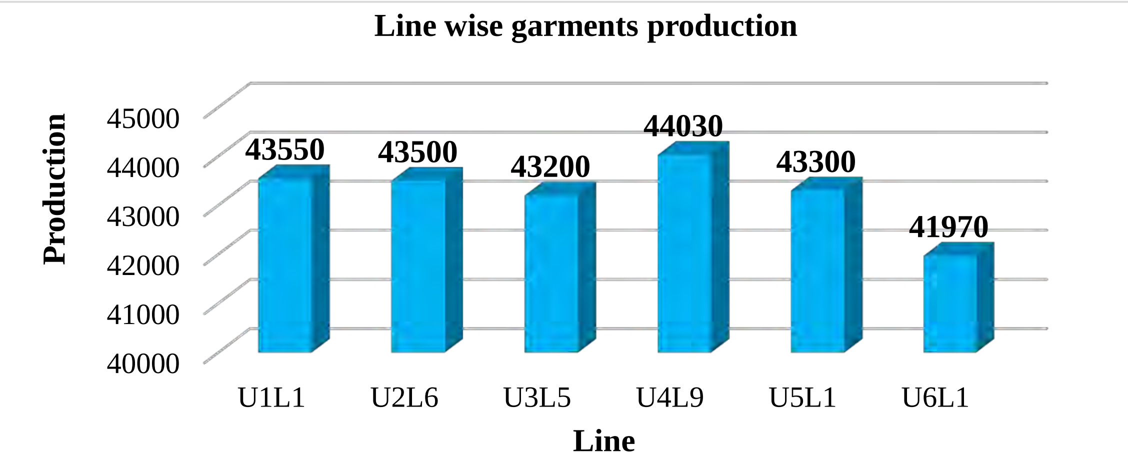

Figure 5.17: Graph of line wise garments production in February-2019

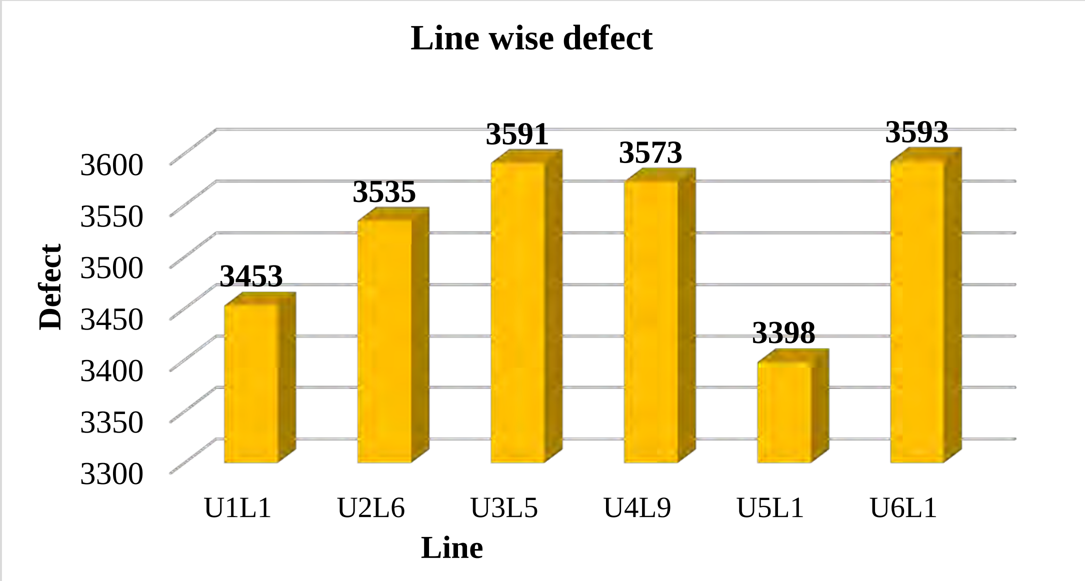

Figure 5.18: Graph of line wise defects in February-2019.

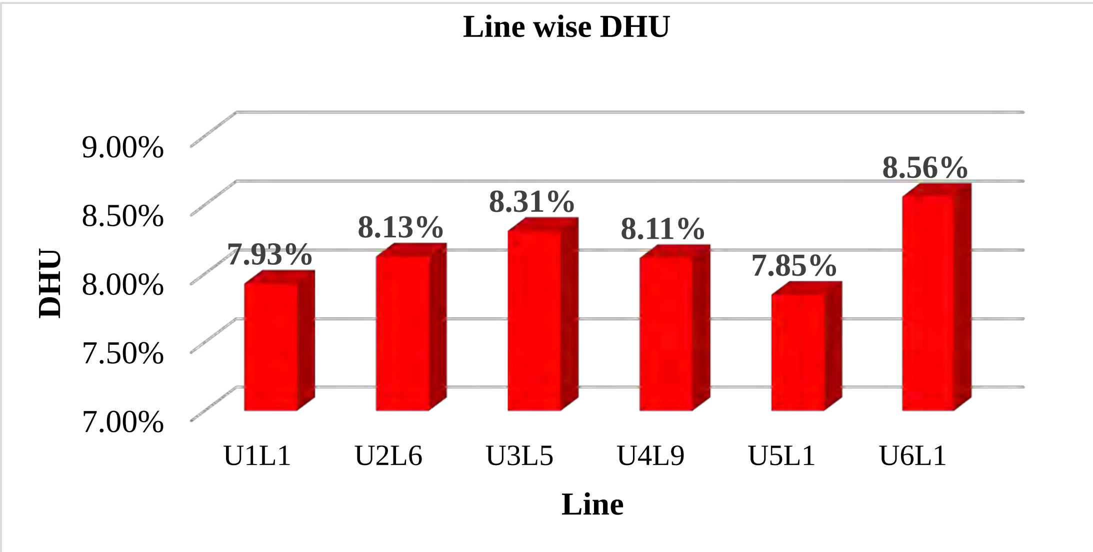

Figure 5.19: Graph of line wise DHU in February-2019.

5.5. Defect Category wise DHU of Selected 6 Lines together of Month-February-2019

Defect category wise DHU of the selected 6 lines together were analyzed against the data of Month-February-2019 and improved result was found as like presented in the table 5.5. Specially the DHU rate of the selected 14 defects for Fishbone diagram, significantly reduced i.e. level of quality in the sewing processes significantly improved. Hence, it shows that DHU rate can be reduced by analyzing and developing solutions of each defects of sewing processes in garments manufacturing industries of Bangladesh.

Table 5.5: DHU of selected 6 lines together of Month-February-2019.

Monthly Summary of DHU of selected 6 lines together of Month-February-2019.				
Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	259550	1095	0.42%
2	Waviness		408	0.16%
3	Needle Mark		266	0.10%
4	Unsecured Security Tack		280	0.11%
5	Uneven Hem		309	0.12%
6	Uneven Joint stich		603	0.23%
7	Measurement Deviation		428	0.16%
8	Open seam		439	0.17%
9	Uneven Gathering		373	0.14%
10	Puckering		525	0.20%
11	Pleat		411	0.16%
12	Raw edge		625	0.24%
13	Slanted		346	0.13%
14	Skip stitch		1697	0.65%
15	Shading		1191	0.46%
16	Wrong Sewing Thread Used		262	0.10%
17	Twisting		396	0.15%
18	Uneven Sleeve / Leg length		386	0.15%
19	Point Up-down		578	0.22%
20	Un-cut thread		4680	1.80%
21	Lose Thread		923	0.36%
22	Loose Stitch		322	0.12%
23	Wrong Stitch per Inch (SPI)		323	0.12%
24	Uneven Neck Width		358	0.14%
25	Oil Sport		1090	0.42%
26	Dirty Spot		796	0.31%
27	Down/Un-even Stitch		307	0.12%
28	Wrong Label Position		226	0.09%
29	Scissor Cut		137	0.05%
30	Label Mistake		360	0.14%
31	Size Mistake		607	0.23%
32	Label Missing		261	0.10%
33	Security Tack Missing		135	0.05%
34	Button Missing		0	0.00%
35	Bow Missing		0	0.00%
Total			21143	8.15%

5.6. Comparative Analysis of Data of Defects

Based on the Pareto Analysis Chart, data for 1st 14 defect were collected from the selected 6 lines before and after implementation of developed solutions for comparative analysis. Defect wise total defects of the selected 6 lines together of month February-2019 after implementation of the developed solutions and the 3- month average defects of the selected 6 lines together before implementation of the solutions and their respective DHU rate are presented in table 5.6.

Table 5.6: Comparative analysis of defects data after and before the solutions implementation.

Comparative analysis of first 14 defects of selected lines							
Serial No	Defect Name	Data Comparison of February-2019 against Average of November-18, December-18 and Juanuary-19					
		Defect			DHU		
		After	Before	Decrease	After	Before	Decrease
1	Un-cut thread	4680	9305	4625	1.80%	3.71%	1.91%
2	Shading	1191	5130	3939	0.46%	1.78%	1.32%
3	Skip stitch	1697	4110	2413	0.65%	1.53%	0.88%
4	Broken Stitch	1095	3021	1926	0.42%	1.28%	0.85%
5	Oil Sport	1090	2680	1590	0.42%	1.07%	0.65%
6	Lose Thread	923	2311	1388	0.36%	0.92%	0.56%
7	Point Up-down	578	2109	1531	0.22%	0.81%	0.59%
8	Dirty Spot	796	1930	1134	0.31%	0.73%	0.43%
9	Raw edge	625	1811	1186	0.24%	0.66%	0.42%
10	Uneven Joint stich	603	1521	918	0.23%	0.61%	0.38%
11	Open seam	439	1330	891	0.17%	0.53%	0.36%
12	Puckering	525	1211	686	0.20%	0.45%	0.24%
13	Size Mistake	607	1023	416	0.23%	0.37%	0.14%
14	Wrong Stitch per Inch (SPI)	396	830	434	0.15%	0.31%	0.15%
Total		15245	38322	23077	5.87%	14.75%	8.88%

The data comparison of defects and DHU of the selected 14 defects are shown in the following frequency diagram. From the frequency diagram, it is observed that, significant amount of improvement in defects reduction and DHU reduction is achieved.

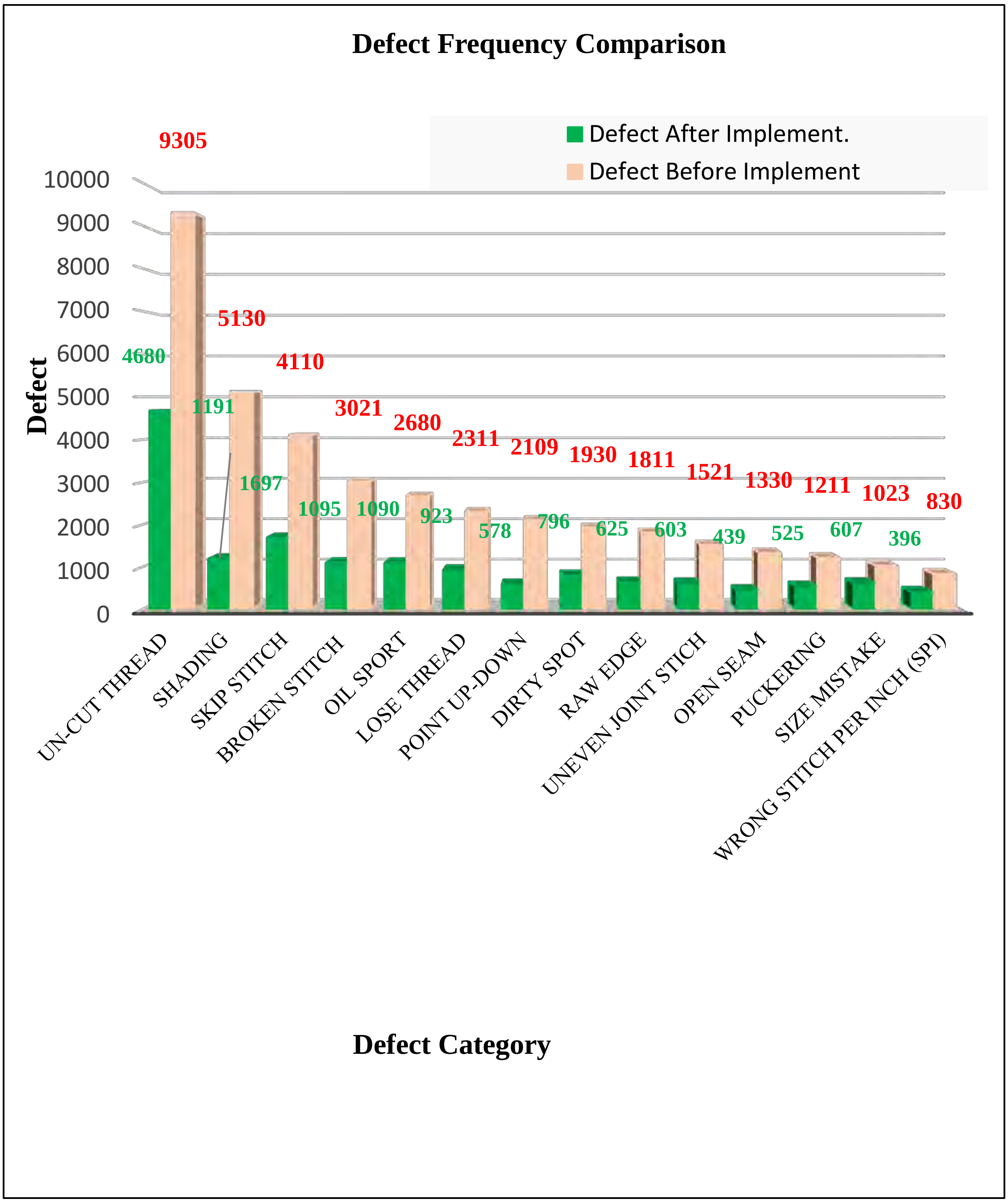

Figure 5.20: Comparison of defect frequency before and after developed solutions implementation.

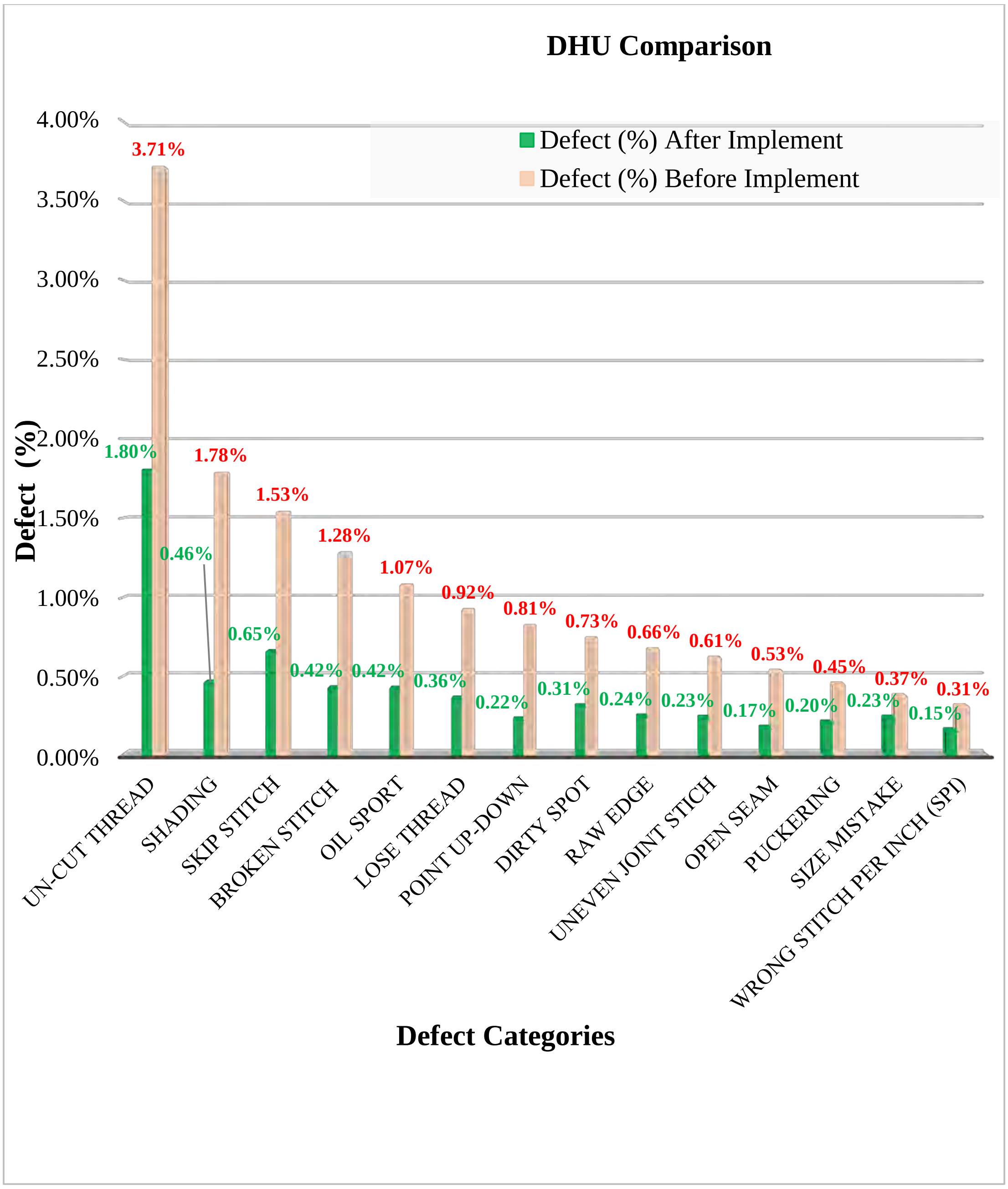

Figure 5.21: Comparison of DHU before and after implementation of the developed solutions.

5.7. Line wise Comparative Analysis of Data of Defects

Defects and DHU rate for each selected line and all lines together are shown in table 5.7 and figure 5.22 and 5.23. Here relevant data of month February-2019 after the implementation of the developed solutions of the problems and the data of the same lines before implementation of the solutions are also shown. Data of the following table and graph represent the outcome this research paper. Over all DHU of the selected 6 lines together reduced from 17.28% to 8.15% by an amount of 9.14% which is shown in figure 5.23.

Table- 5.7: Comparison of defects and DHU before and after implementation of the developed solutions.

Production Unit	Selected Line No	3-Month Data Summary (November-18,December-18 and January-19)			Data Summary of Month-February-19			Reduction of Defect & DHU After Implementation of the Solutions.	
		Inspected Garments	Defects	DHU	Inspected Garments	Defects	DHU	Defects	DHU
1	1	129380	23715	18.33%	43550	3453	7.93%	20262	10.40%
2	6	129050	19887	15.41%	43500	3535	8.13%	16352	7.28%
3	5	129800	23200	17.87%	43200	3591	8.31%	19609	9.56%
4	9	128980	21744	16.86%	44030	3573	8.11%	18171	8.74%
5	1	128450	19648	15.30%	43300	3398	7.85%	16250	7.45%
6	1	123970	24825	20.03%	41970	3593	8.56%	21232	11.46%
Total / Average	6	769630	133019	17.28%	259550	21143	8.15%	111876	9.14%

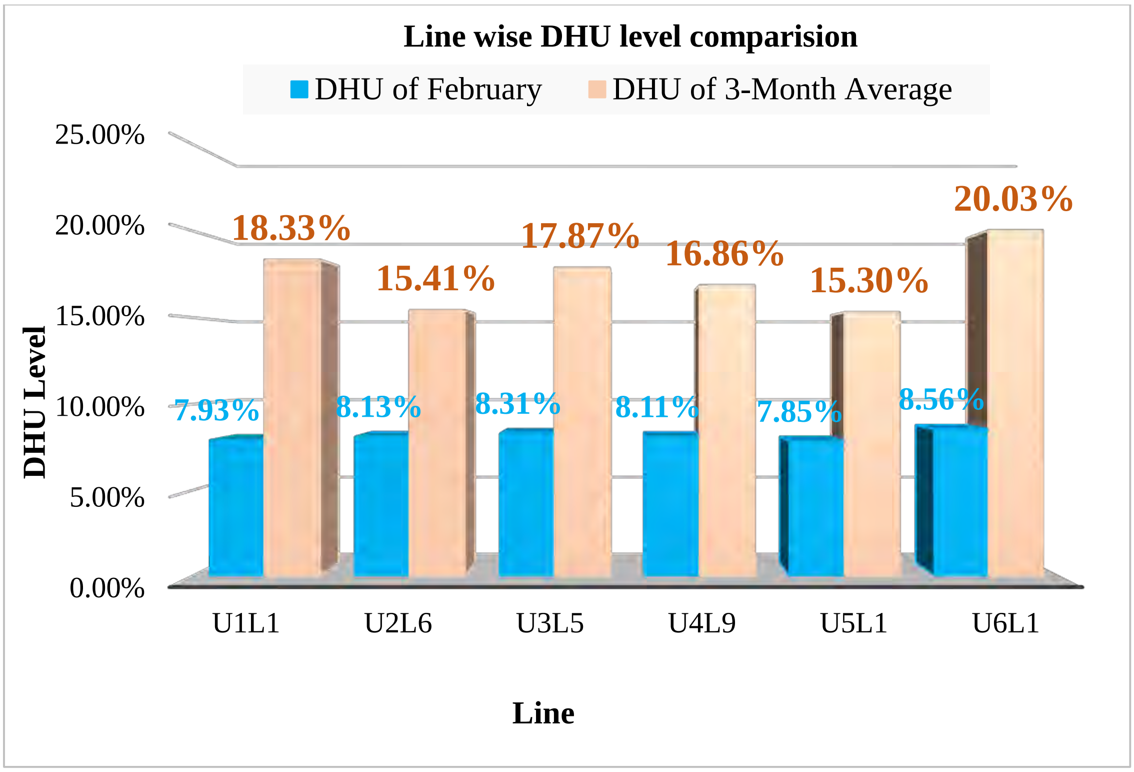

Figure-5.22: Line wise comparison of DHU level before and after implementation of the developed solutions.

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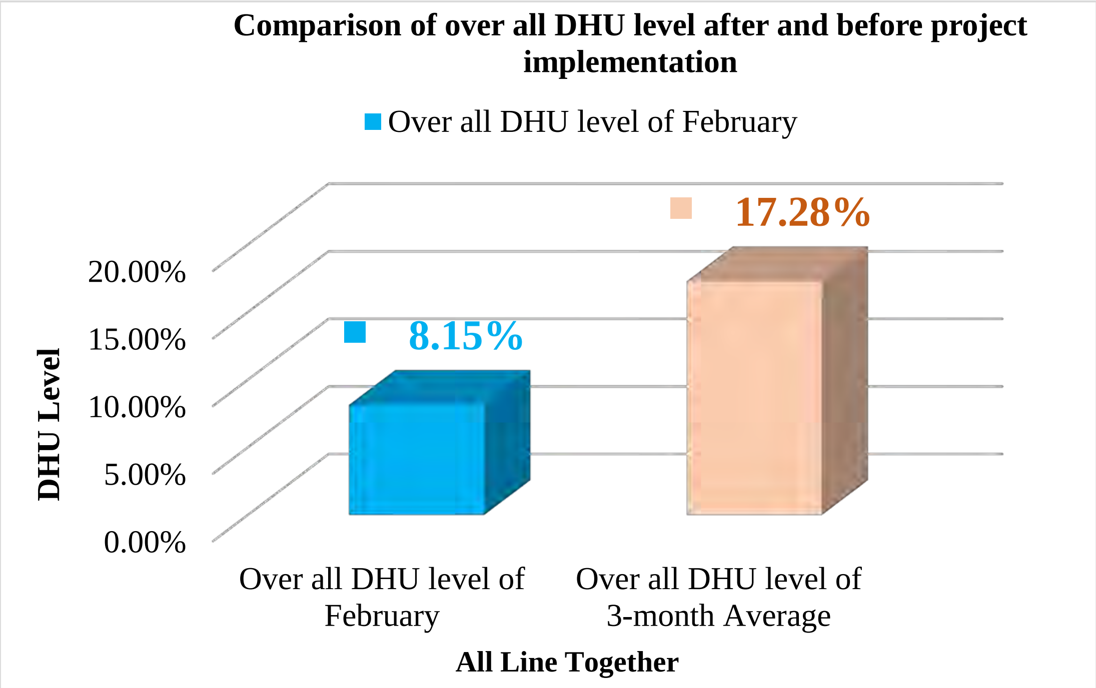

Figure 5.23: Comparison of average DHU level of 6 lines before and after implementation of the developed solutions

5.8. Comparison of Efficiency Level

Quality and productivity in terms of efficiency are closely related. If quality improves, efficiency level also improves because rework and wastage reduce due to improved quality level. In this research paper, quality improvement is first objective, but improving efficiency level is the another associated objective which can be achieved as the quality level improves. Here the efficiency level of the selected each and combined 6 lines before and after implementation of the developed solutions of the selected problems are also analyzed to find the desired result. In following table 5.8 and figure 5.24, 5.25 and 5.26, improved efficiency level of each lines and all line together after implementation of developed solutions are shown. Overall efficiency level of the selected 6 lines together improved from 56.22 to 63.77 by amount of 7.55 which is shown in figure 5.27.

Table 5.8: Line wise efficiency and per head per hour productivity level of month February-2019.

Production Unit/Floor	Selected Line No	Efficiency	Productivity per Head per Hour
		Feb-19	Feb-19
1	1	64.51%	4.93
2	6	63.28%	4.78
3	5	66.09%	5.22
4	9	62.93%	5.32
5	1	64.55%	4.90
6	1	61.25%	5.07
Total /Average	6	63.77%	5.04

5.8.1. Line wise efficiency level of month –February-2019

The developed solutions of the 1st 14 defects by root causes analysis were applied to the selected 6 production lines and corresponding daily data of month February-2019 were kept for comparison with the previous conditions. The monthly average efficiency level of the selected 6 lines of the month February were found like the below graph shown in figure 5.24.

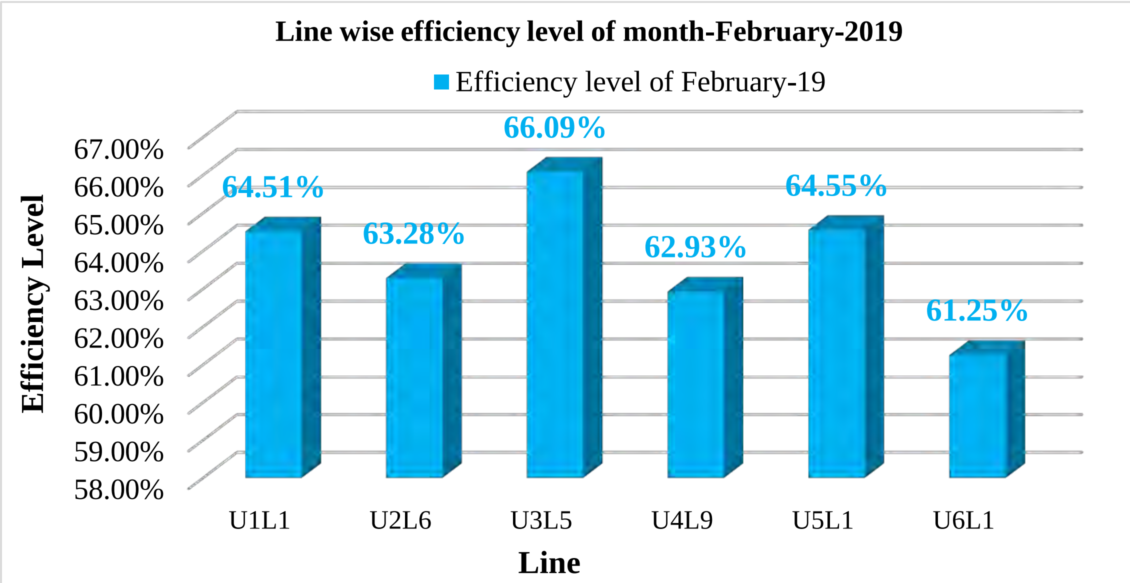

Figure 5.24: Line wise efficiency level of month –February-2019

5.8.2. Comparison of efficiency level after implementing developed solutions

Efficiency level of the selected 6 lines of the 6 production floors after implementing the developed solutions by root causes analysis have been compared with the previous 3-month average efficiency level of these lines and this comparison are shown here by the below graph.

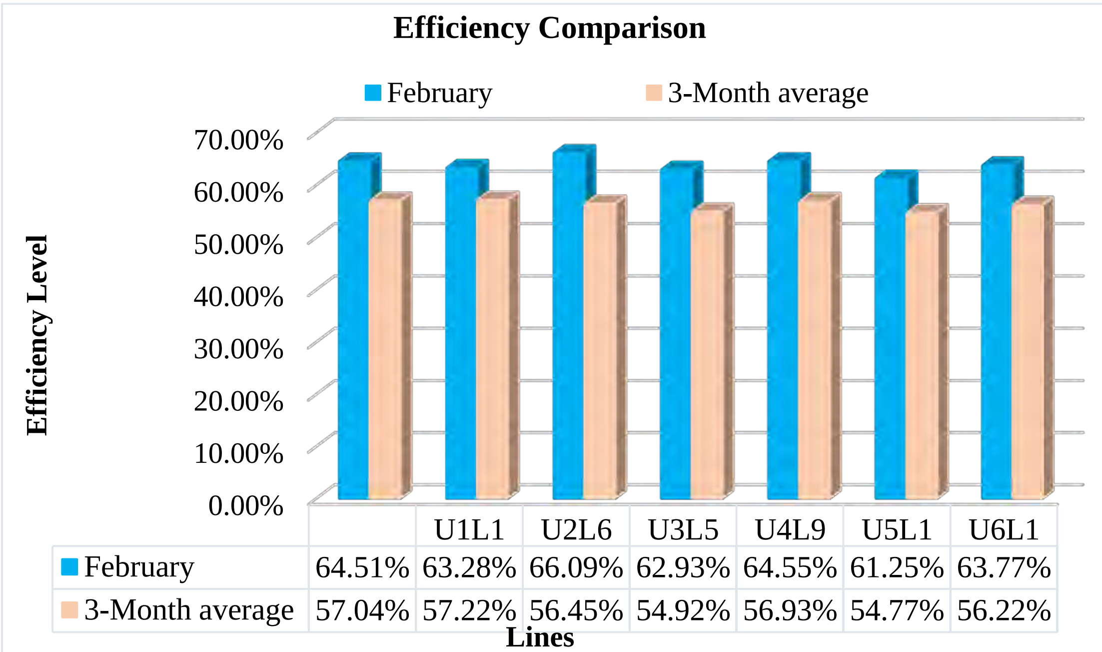

Figure 5.25: Comparison of efficiency level of 6 lines after and before implementation of developed solutions.

Overall average efficiency level of the selected 6 lines of the 6 production floors after implementing the developed solutions by root causes analysis have been compared with the previous efficiency level of these lines and this comparison are shown here by the below graph in figure 5.26.

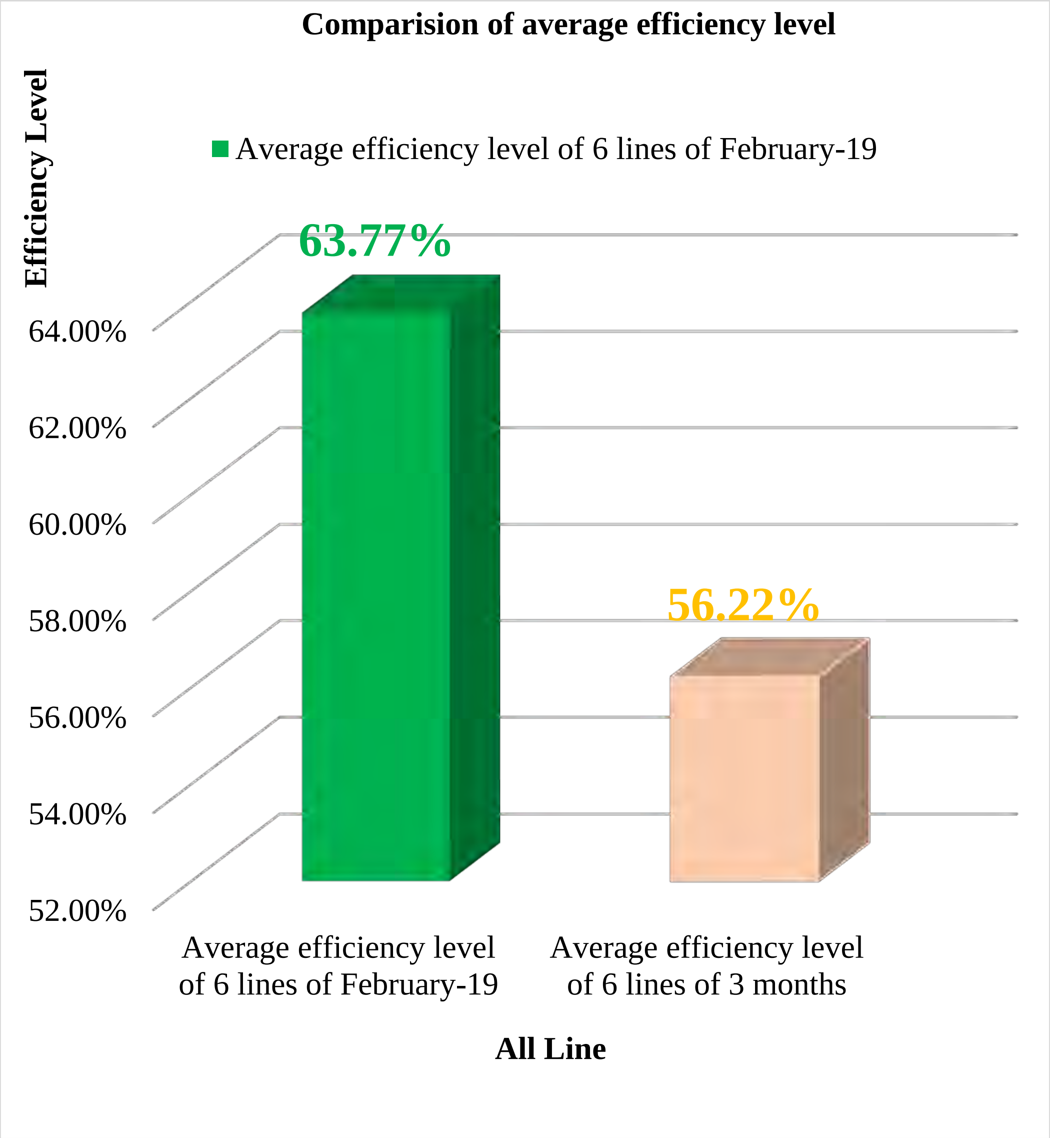

Figure 5.26: Comparison of average efficiency level of 6 lines after and before implementation of developed solutions.

CHAPTER 6
CONCLUSION

6.1. Introduction

This research work can contribute the RMG sector of Bangladesh in controlling & improving its sewing quality level and reducing production cost by systematic identifying and minimizing various defects which happen during sewing section of garment manufacturing industries. So, this paper can help for future study on other sections like Knitting, Dyeing and Cutting of garments industries. Better defining of problems helps to better solutions of the problems. The DMAIC methodology is a Six Sigma tool that is very much effective to define and identify the problems has been used in this research work.

6.2. Conclusion

It is now obvious that quality of garments is getting the 1st priority to every buyer and final customer. So it is the question of survival for any garments manufacturing industry to achieve right quality at right time. In this paper, expected result has been found in case of sewing quality improvement by reducing DHU level 17.28% to 8.15% for the selected lines. Efficiency level also has improved by7.55% for those lines. This project will be highly beneficial to apply for all lines in full extend to get higher benefits. This paper solved only 14 selected defects not all defects and for more defects it will be lengthy job to do. This research paper mainly focused on knit garments items like T-Shirts, Polo Shirts, Jackets etc. but result of this research paper can be apply in oven Shirts and Bottoms industries as well as Denim Jackets and bottoms industries. This research paper focused only sewing quality of garments industries, other parts like knitting, fabrics, dyeing, printing, embroidery, cutting are not covered in this paper. There is also significant amount of quality defects occur in these parts of complete garments manufacturing system. Sewing part is the mother part of garments manufacturing system, that's why sewing section has been chosen for this research work.

6.3. Future work

Some recommendations are given below for future work:

This research work can help in future work-

To identify and reduce defects in other sections of garments industries like knitting, dyeing, printing and cutting.

To identify and remove the causes of problems of RMG industries in the area of production, supply chain, costs etc.

To improve quality and productivity of others manufacturing industries.

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APPENDICES

Appendix 1: Monthly summary of defects for selected lines of month - November-2018.

Monthly summary of defects for selected lines of month - november-2018				
Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	255980	3021	1.18%
2	Waviness		450	0.18%
3	Needle Mark		285	0.11%
4	Unsecured Security Tack		390	0.15%
5	Uneven Hem		280	0.11%
6	Joint stich		1521	0.59%
7	Measurement Deviation		515	0.20%
8	Open seam		1330	0.52%
9	Uneven Gathering		360	0.14%
10	Puckering		1211	0.47%
11	Pleat		395	0.15%
12	Raw edge		1811	0.71%
13	Slanted		321	0.13%
14	Oil Spot		4110	1.61%
15	Shading		5130	2.00%
16	Wrong Sewing Thread Used		220	0.09%
17	Wrong Stitch per Inch (SPI)		830	0.32%
18	Uneven Sleeve / Leg length		380	0.15%
19	Point Up-down		2109	0.82%
20	Un-cut thread		9305	3.64%
21	Lose Thread		2311	0.90%
22	Loose Stitch		445	0.17%
23	Twisting		660	0.26%
24	Uneven Neck Width		365	0.14%
25	Skip Stitch		2680	1.05%
26	Dirty Spot		1930	0.75%
27	Down/Un-even Stitch		318	0.12%
28	Wrong Label Position		233	0.09%
29	Scissor Cut		130	0.05%
30	Label Mistake		320	0.13%
31	Size Mistake		1023	0.40%
32	Label Missing		251	0.10%
33	Security Tack Missing		131	0.05%
34	Button Missing		27	0.01%
35	Bow Missing		31	0.01%
Total			44829	17.51%

Appendix 2: Monthly summary of defects for selected lines of month - December-2018.

Monthly summary of defects for selected lines of month - december-2018.				
Serial No	Defect Name	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	252450	3350	1.33%
2	Waviness		460	0.18%
3	Needle Mark		290	0.11%
4	Unsecured Security Tack		260	0.10%
5	Uneven Hem		295	0.12%
6	Joint stich		1589	0.63%
7	Measurement Deviation		495	0.20%
8	Open seam		1350	0.53%
9	Uneven Gathering		370	0.15%
10	Puckering		1090	0.43%
11	Pleat		415	0.16%
12	Raw edge		1699	0.67%
13	Slanted		330	0.13%
14	Oil Spot		3990	1.58%
15	Shading		4495	1.78%
16	Wrong Sewing Thread Used		260	0.10%
17	Wrong Stitch per Inch (SPI)		730	0.29%
18	Uneven Sleeve or Leg length		375	0.15%
19	Point Up-down		2023	0.80%
20	Un-cut thread		9025	3.57%
21	Lose Thread		2311	0.92%
22	Loose Stitch		450	0.18%
23	Twisting		692	0.27%
24	Uneven Neck Width		377	0.15%
25	Skip Stitch		2780	1.10%
26	Dirty Spot		1820	0.72%
27	Down/Un-even Stitch		332	0.13%
28	Wrong Label Position		211	0.08%
29	Scissor Cut		131	0.05%
30	Label Mistake		339	0.13%
31	Size Mistake		896	0.35%
32	Label Missing		263	0.10%
33	Security Tack Missing		121	0.05%
34	Button Missing		35	0.01%
35	Bow Missing		23	0.01%
Total			43672	17.30%

Appendix 3: Monthly summary of defects for selected Lines of month - January-2019.

Monthly summary of defects for selected lines of month - January-2019				
Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	261200	3445	1.32%
2	Waviness		438	0.17%
3	Needle Mark		275	0.11%
4	Unsecured Security Tack		290	0.11%
5	Uneven Hem		313	0.12%
6	Joint stich		1587	0.61%
7	Measurement Deviation		458	0.18%
8	Open seam		1369	0.52%
9	Uneven Gathering		383	0.15%
10	Puckering		1124	0.43%
11	Pleat		441	0.17%
12	Raw edge		1601	0.61%
13	Slanted		336	0.13%
14	Oil Spot		3699	1.42%
15	Shading		4086	1.56%
16	Wrong Sewing Thread Used		262	0.10%
17	Wrong Stitch per Inch (SPI)		788	0.30%
18	Uneven Sleeve or Leg length		383	0.15%
19	Point Up-down		2123	0.81%
20	Un-cut thread		10223	3.91%
21	Lose Thread		2423	0.93%
22	Loose Stitch		472	0.18%
23	Twisting		512	0.20%
24	Uneven Neck Width		368	0.14%
25	Skip Stitch		2790	1.07%
26	Dirty Spot		1893	0.72%
27	Down/Un-even Stitch		317	0.12%
28	Wrong Label Position		236	0.09%
29	Scissor Cut		134	0.05%
30	Label Mistake		357	0.14%
31	Size Mistake		928	0.36%
32	Label Missing		273	0.10%
33	Security Tack Missing		129	0.05%
34	Button Missing		36	0.01%
35	Bow Missing		26	0.01%
Total			44518	17.04%

Appendix 4: 3-month (November, December & January) summary of defects for selected lines (2018-2019)

3-month summary of defects for selected lines (2018-2019)				
Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	769630	9816	1.28%
2	Waviness		1348	0.18%
3	Needle Mark		850	0.11%
4	Unsecured Security Tack		940	0.12%
5	Uneven Hem		888	0.12%
6	Joint stich		4697	0.61%
7	Measurement Deviation		1468	0.19%
8	Open seam		4049	0.53%
9	Uneven Gathering		1113	0.14%
10	Puckering		3425	0.45%
11	Pleat		1251	0.16%
12	Raw edge		5111	0.66%
13	Slanted		987	0.13%
14	Oil Spot		11799	1.53%
15	Shading		13711	1.78%
16	Wrong Sewing Thread Used		742	0.10%
17	Wrong Stitch per Inch (SPI)		2348	0.31%
18	Uneven Sleeve or Leg length		1138	0.15%
19	Point Up-down		6255	0.81%
20	Un-cut thread		28553	3.71%
21	Lose Thread		7045	0.92%
22	Loose Stitch		1367	0.18%
23	Twisting		1864	0.24%
24	Uneven Neck Width		1110	0.14%
25	Skip Stitch		8250	1.07%
26	Dirty Spot		5643	0.73%
27	Down/Un-even Stitch		967	0.13%
28	Wrong Label Position		680	0.09%
29	Scissor Cut		395	0.05%
30	Label Mistake		1016	0.13%
31	Size Mistake		2847	0.37%
32	Label Missing		787	0.10%
33	Security Tack Missing		381	0.05%
34	Button Missing		98	0.01%
35	Bow Missing		80	0.01%
Total			133019	17.28%

Appendix 5: Line wise monthly summary of DHU for the selected lines.

Production Unit	Selected Line	January-19			Deccember-18			November-18		
		Inspected Garments	Defects	DHU (%)	Inspected Garments	Defects	DHU (%)	Inspected Garments	Defects	DHU (%)
1	1	44200	7830	17.71%	42300	8130	19.22%	42880	7755	18.09%
2	6	43500	6827	15.69%	42300	6908	16.33%	43250	6152	14.22%
3	5	44200	7990	18.08%	43200	7440	17.22%	42400	7770	18.33%
4	9	44030	7233	16.43%	42250	6515	15.42%	42700	7996	18.73%
5	1	43300	6285	14.52%	42100	7123	16.92%	43050	6240	14.49%
6	1	41970	8353	19.90%	40300	7556	18.75%	41700	8916	21.38%
Total	6	261200	44518	17.04%	252450	43672	17.30%	255980	44829	17.51%

Appendix 6: Line wise 3-month average of production, defect and DHU for the selected lines.

Production Unit	Selected Line No	3- Month Average		
		Inspected Garments	Defects	DHU (%)
1	1	43127	7905	18.34%
2	6	43017	6629	15.42%
3	5	43267	7733	17.87%
4	9	42993	7248	16.86%
5	1	42817	6549	15.31%
6	1	41323	8275	20.01%
Total /Average	6	256543	44340	17.28%

Appendix 7: Line wise monthly and 3-month average efficiency and productivity of selected lines.

Production Unit	Selected Line No	Efficiency				Productivity/Hour/Head			
		Jan-19	Dec-18	Nov-18	3-Month average	Jan-19	Dec-18	Nov-18	3-Month
1	1	55.33%	58.75%	57.00%	57.04%	4.55	4.27	5.10	4.62
2	6	53.14%	57.91%	61.27%	57.22%	4.20	5.04	4.81	4.65
3	5	52.44%	60.77%	56.45%	56.45%	4.40	4.65	4.87	4.63
4	9	54.50%	54.07%	56.07%	54.92%	4.25	5.03	4.31	4.50
5	1	58.65%	51.65%	59.07%	56.93%	4.45	5.85	4.35	4.79
6	1	52.43%	52.99%	58.64%	54.77%	4.63	4.48	4.34	4.48
Total /Average	6	54.42%	56.02%	58.08%	56.22%	4.41	4.88	4.63	4.61

Appendix 8: Monthly summary of defects for selected lines of month - February-2019

Monthly Summary of Defects for Selected Lines of Month - February 2019				
Serial No	Defect List	Inspected Garments	Defect Frequency	DHU (%)
1	Broken Stitch	259550	1095	0.42%
2	Waviness	259550	408	0.16%
3	Needle Mark	259550	266	0.10%
4	Unsecured Security Tack	259550	280	0.11%
5	Uneven Hem	259550	309	0.12%
6	Joint stich	259550	603	0.23%
7	Measurement Deviation	259550	428	0.16%
8	Open seam	259550	439	0.17%
9	Uneven Gathering	259550	373	0.14%
10	Puckering	259550	525	0.20%
11	Pleat	259550	411	0.16%
12	Raw edge	259550	625	0.24%
13	Slanted	259550	346	0.13%
14	Oil Spot	259550	1697	0.65%
15	Shading	259550	1191	0.46%
16	Wrong Sewing Thread Used	259550	262	0.10%
17	Wrong Stitch per Inch (SPI)	259550	396	0.15%
18	Uneven Sleeve or Leg length	259550	386	0.15%
19	Point Up-down	259550	578	0.22%
20	Un-cut thread	259550	4680	1.80%
21	Lose Thread	259550	923	0.36%
22	Loose Stitch	259550	322	0.12%
23	Twisting	259550	323	0.12%
24	Uneven Neck Width	259550	358	0.14%
25	Skip Stitch	259550	1090	0.42%
26	Dirty Spot	259550	796	0.31%
27	Down/Un-even Stitch	259550	307	0.12%
28	Wrong Label Position	259550	226	0.09%
29	Scissor Cut	259550	137	0.05%
30	Label Mistake	259550	360	0.14%
31	Size Mistake	259550	607	0.23%
32	Label Missing	259550	261	0.10%
33	Security Tack Missing	259550	135	0.05%
34	Button Missing	259550	0	0.00%
35	Bow Missing	259550	0	0.00%
Total		259550	21143	8.15%

Appendix 9: Line wise monthly summary of DHU for the selected lines of Month-February-2019

Production Unit	Selected Line No	Feb-19		
		Inspected Garments	Defects	DHU (%)
1	1	43550	3453	7.93%
2	6	43500	3535	8.13%
3	5	43200	3591	8.31%
4	9	44030	3573	8.11%
5	1	43300	3398	7.85%
6	1	41970	3593	8.56%
Total /Average	6	259550	21143	8.15%