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Reducing Sewing Defects to Increase Productivity in the Apparel Industry of Bangladesh by Integrating Lean Methodology

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Abstract

The purpose of this study is to determine how the Bangladeshi garment industry's sewing defect reduction and productivity enhancement are affected by the Plan, Do, Check, Act (PDCA) and 5S (Sort, Set in order, Shine, Standardize, Sustain) techniques. One of the main reasons for production delays and increased costs is sewing defects. By reducing defects, improving Overall Equipment Effectiveness (OEE), and methodically using integrated PDCA concepts, the study aims to streamline and expand the production flowline while increasing throughput. To continuously evaluate and improve the sewing process, the 5S method is also employed. Tools like cause-effect diagrams and Pareto charts were used to identify the defect correctly. The OEE was used to evaluate the actual efficiency. The integration of 5S and PDCA as a lean methodology was utilized to minimize the defect rate and maximize quality to improve efficiency. For this purpose, data was collected from some renowned factories in Bangladesh. This mixed-integrated methodology is used in the study to integrate quantitative defect analysis with worker satisfaction along with efficiency surveys. The findings should offer valuable insights to the RMG industry in Bangladesh, as producers seek sustainable methods to increase productivity and enhance product quality while mitigating the impact of sewing errors on their production procedures. OEE was increased by almost 3-4% through this research.

Keywords: Sewing, Productivity, PDCA, Lean, Efficiency, Simulation.

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1|Introduction

The readymade garments industry accelerates the development of Bangladesh. The Made in Bangladesh label has also enhanced Bangladesh's reputation and elevated its brand recognition internationally. Once, the term 'Bottomless basket' was used to identify Bangladesh, but now the bottomless basket become a basket full of wonders. Despite the large population, limited resources, and natural disasters, the country has maintained an annual average GDP growth rate of 6% and has brought significant social and human development [1]. One of the driving forces behind this incredible growth is the garment sector. In the 1980s, Bangladesh's garments sector progressed to where it is today. Late Nurul Quader Khan founded the readymade garments industry. He sent a group of 130 trainees to South Korea in 1978 to learn how to make readymade garments [2].

Other responsible and diligent business people followed in his footsteps and started investing in the RMG sector nationwide. Since then, the Bangladeshi Garments sector has not looked back. Currently, there are more than 7,000 garment industries in the country. According to newly disclosed Export Promotion Bureau data, in fiscal year 2021-22, RMG exports earned $42.613 billion. In 2020-21, RMG exports earned $31.456 billion; in the first nine months of fiscal 2022-23, RMG exports earned 35.252 billion. In FY 2022, the RMG sector contributes 9.5% of GDP. RMG contributes 83% of all export earnings for Bangladesh [3]. The rate was increased in a proportional order concerning the production rate of this particular sector, as shown in some research [4]. The apparel industry has several high-pressure jobs. Any sewing flaws may develop in this circumstance. Thus, pressure is the primary contributing factor to stitching mistakes. According to the particular apparel industry, the most frequent sewing flaws are broken stitches, open seams, pleats, skip stitches, label flaws, and points up and down [5]. Broken stitches can occur as a result of both worker and equipment efficiency issues. The machine's dust caused a skip stitch to occur. Because of this, operators must practice routine machine cleaning. The simple problem is that the label is missing. However, it is detrimental to observe. With the help of specialists, discussions, graphical representations, and continual improvement, most fundamental problems are quickly discovered and should be solved [6]. As a major contributor to Bangladesh's export sector, the garments industry is important to the country's economy. However, this sector also faces some difficulties with quality assurance, particularly in Sewing. In the garment industry, sewing defects are generally of two types: repairable and non-repairable. Repairable defects in garment factories result in rework, while non-repairable defects result in rejection. Sewing defects can result in product rejections, higher manufacturing costs, unsatisfied customers, and negatively impact the sector's competitiveness [6]. Very few items were rejected in the garment manufacturing process after shipment. Many producers claim that garments are soft goods and that any damage is irreparable, resulting from poor-quality raw materials, bad manufacturing, or careless employee behavior. The entire procedure cost is lost if a product defect is found at the finish line or during the final inspection because the product cannot be exported. Manufacturers occasionally modify flawed products to make them exportable, but doing so comes at an additional cost and uses more resources, which reduces the company's profit. Some swing section flaws occur during production; these should be minimized to ensure the garment's quality. The flaws affect the factory's overall quality; based on the company's daily rework rate, the flaws cause a rework rate of approximately 7%, which lowers the sewing section's productivity and efficiency [7]. One of the main goals of lean manufacturing is to reduce the time employees spend in the production system and the amount of time that suppliers and customers must respond. It is quite similar to another concept called Just-In-Time (JIT) production (sometimes referred to as JIT manufacturing) [8]. To match production to demand, JIT manufacturing prioritizes productivity, efficiency, and the reduction of "wastes" for the manufacturer and provider of goods [9]. Lean manufacturing is a JIT approach that further reduces cycle, flow, and throughput times by eliminating tasks that do not provide value to the customer [10]. Lean manufacturing also includes those who work in marketing and customer service but are not directly involved in production. The Japanese automaker Toyota created the Toyota Production System (TPS), also referred to as The Toyota Way, as an operating approach in the 1950s and 1960s following World War II. The Toyota system was built on the two pillars of JIT inventory management and automated quality control [11]. The waste of excess inventories of finished goods and raw materials; waste of overproduction (producing more than is currently needed); waste of overprocessing (processing or making parts beyond the standard expected by customers); waste of transportation (unnecessary movement of people and goods inside the system); and waste of excess motion (mechanizing or automating) are the seven wastes ('Mud' in Japanese), which were first identified by Toyota engineer Shigeo Shingo [12]. The well-known challenges associated with implementing lean and a lack of experience with the manufacturing industry may be caused by inadequate managerial and employee training [13]. It is, therefore, crucial to review the literature on the effects of lean on RMG production [14]. The tools not only discover the defects but also find ways to minimize them to maximize a particular system's expected outcome and efficiency. In this way, Lean tools, such as DMAIC, algorithm, etc., were utilized before for defect reduction [15]. Some studies use tools like 5S and PDCA separately [4], [16]. However, this study integrates both methodologies to make it more significant.

2 | Related Works

With lean manufacturing, an industry may boost productivity in the cutthroat world of industrialization while minimizing waste within a suitable manufacturing operation [17]. Lean manufacturing's main objective is to reduce waste while pursuing continuous improvement, which provides customers with long-term value [18]. Customers will pay for the value of the services they receive, not for defects, according to the fundamental premise of lean manufacturing [19]. The greatest way to change an organization's culture is to use the lean method with an effective production management system [20]. Additionally, in the age of industrialization and automation, the industry and the consumer require sustainable progress with profit. Implementing lean methods may help both achieve this. In 1999, Quality was defined by Jilcha et al. [21] as product attributes that satisfy and meet consumer needs. Income correlates inversely with quality [21]. Usually, adding additional or higher-quality features necessitates an investment [22], which raises expenses. "quality" refers to the absence of flaws—the absence of mistakes that require redoing work (rework) or that cause field failures, customer complaints, and other issues [7]. It is necessary to ensure that their costs will bring a clear benefit before acquiring new technological tools and management software products [23]. Lean implementation is crucial for doing this. Lean thinking aims to increase productivity by shifting the control focus from optimizing individual technologies, assets, and vertical departments to optimizing the flow of goods and services through entire price streams that move horizontally through departments, properties, and technologies to clients [6]. It includes holding out for supplies, data, tools, equipment, etc. JIT delivery of all resources is required by lean—neither too early nor too late [24]. The top seven defect positions, where 80% of all faults occur, are found using Pareto analysis, and these should be the main areas of concern to reduce the defect percentage [7]. Alam and Huda [25] used FMEA and an Ishwikawa diagram as quality tools to categorize faults according to when they occurred. Wilson et al. define root cause analysis as an analytical tool. They also mentioned the tool's value in conducting a comprehensive system-based review of the principal vulnerabilities and implementing fixes. The PDCA cycle helps to plan for continuously improving quality by removing defects [6]. Cause-and-effect diagrams are used to identify the leading causes of a defect and take corrective action for the causes identified in the diagram [7].

In addition, despite the positive effects the growth of the RMG industry has had on the economies of developing nations and the large number of low-skilled jobs it has generated [25], the sector has frequently come under fire for low pay, lengthy hours, and hazardous and unhealthy working conditions [26]. The criticism became more intense after significant accidents in the garment sector in poor nations, such as the Rana Plaza incident in Bangladesh in 2013. As a result, the international community and international brands pressured clothing manufacturers to enhance OHS [27]. Currently, clothing factories in various developing nations are working to strengthen concurrent production and OHS conditions [28]. As a result, the 5S (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke) difficulties, which virtually always arise in workstations and other areas, are the main issues facing clothing. The 5S principle is a technique used to establish a tidy, clean, and comfortable work environment to boost productivity [29]. The results of the application of the PDCA method can be used to address both qualitative and quantitative data issues that have been widely applied for continuous improvement in the manufacturing and service sectors, as well as a work pattern to improve an organization's system or process and increase productivity [30]. This paper's primary goal is to pinpoint the underlying factors contributing to sewing errors in the Bangladeshi textile sector and continuously enhance the Kaizen (Continuous Improvement) system's ability to reduce errors [31]. The leading causes of stitching errors were discovered using a cause-and-effect analysis [32]. The reduction of sewing flaws is continuously improved using Kaizen [28]. To identify swing defects in a specific product and reduce the pace of rework, use the 5S (Sort, Set-in order, Shine, Standardize, Sustain) and Plan, Do, Check, Act (PDCA) methodologies [33]. The 5S concept and PDCA approach were employed in several prior studies to enhance the working environment while lowering the number of defective goods [34]. These studies employ the 5S idea and the PDCA approach to address issues with worker discipline, equipment sorting, positioning, cleaning, maintenance [35], improving product quality, and decreasing defective goods. Companies can boost efficiency in all areas by serving as case studies [29].

By offering a framework that will detect, quantify, and remove sources of variation in operational processes, it will optimize operational variables and boost process performance with a properly implemented control strategy [36]. The report also identifies the flaws in various industry departments and discusses the quality system currently used in the garment sector. According to the categorization of the flaws, a model was created to provide a perfect remedy for each one [37].

3 | Significance

Today, the RMG industry uses lean manufacturing techniques to boost efficiency and minimize waste. RMG is one of the industries with the highest labor requirements in the world, which promotes RMG enterprises to locate in countries with a ready supply of workers. The RMG market is now experiencing substantial growth, which drives business professionals to constantly advance their technological expertise and enhance the system internally and externally to remain competitive. Lean can be applied by changing processes that result in products that are thought to be less effective and efficient in terms of time, money, and human resources. To increase the quality and effectiveness of services, we therefore require the process management principle as one of the industrial management approaches. Lean is increasingly used in the garments sector to:

- *Increased product quality by reducing sewing defect.*
- *Increased productivity by reducing rework rate and lead time.*
- *Maximize the profit margin.*

4 | Methodology

The research methodology of the study is the main topic of this chapter. The approach chosen for the suggested research will be described in detail. The methodology details have been planned and designed to achieve the project's objectives and goals. Methodology is crucial because it provides a structured approach to solving problems and achieving goals. It establishes clear guidelines and procedures that ensure consistency, accuracy, and reliability in data collection, analysis, and interpretation. A well-defined methodology can produce trustworthy and valid results that others can replicate.

Moreover, the methodology helps to improve decision-making by providing a clear framework for evaluating different options and selecting the most appropriate course of action. It also helps to identify potential sources of bias and error, which can be addressed and minimized through careful planning and execution. Here, the tool selection, steps involved in the research, and research framework of the study will be described. The study provides a review of the recent condition of the output line in production, the constraints of the sewing line, and the challenges of applying PDCA & 5S for reducing sewing defects to increase effective productivity in the apparel industry.

The combination of PDCA and 5S is a powerful approach to continuous improvement in the workplace [38]. The 5S methodology organizes and standardizes the workplace to improve efficiency, safety, and quality. PDCA is a problem-solving approach that involves identifying a problem, developing a plan to address it, implementing the plan, checking the results, and making adjustments as necessary [39]. When combined, PDCA and 5S can identify areas for improvement, develop and implement solutions, and continually monitor progress to ensure sustained success. For this research, 'Silken Sewing Ltd' was chosen for the initial study. Details about that are provided below in Section 5. There were some existing quality control processes. For example, they implemented JIT, FMEA, and PDCA separately. After finding their data about the defect, PDCA and 5S were utilized to minimize the defects and maximize efficiency. The rate of production, defects, and cost calculation were taken from the authority. After implementing the proposed methodology, an improvement was found, as shown in the tables in another section below.

4.1 | Tool Selection

The researcher used a descriptive research design to gather information about existing conditions needed in the chosen field. This research method used a combination of PDCA and 5S to collect relevant data on the current status of Apparel Garments Industries considering different parameters. As a result, we've decided to concentrate our research on the apparel industry. For this reason, we choose PDCA & 5S as a tool for research analysis.

5S: the 5S is a systematic approach to housekeeping that aims to create an environment where people are genuinely committed to implementing and practicing housekeeping.

PDCA: continuous process improvement is achieved through the application of PDCA. It also goes by the name of the never-ending cycle of improvement.

OEE: overall Equipment Effectiveness (OEE) is a worldwide best practice and lean manufacturing tool for tracking, assessing, and enhancing production process effectiveness. It could be an assembly line, machine cell, packing line, filling machine, etc. One of the most critical performance factors for every production facility, workshop, or individual station is OEE, one of the finest basic ideas in lean manufacturing.

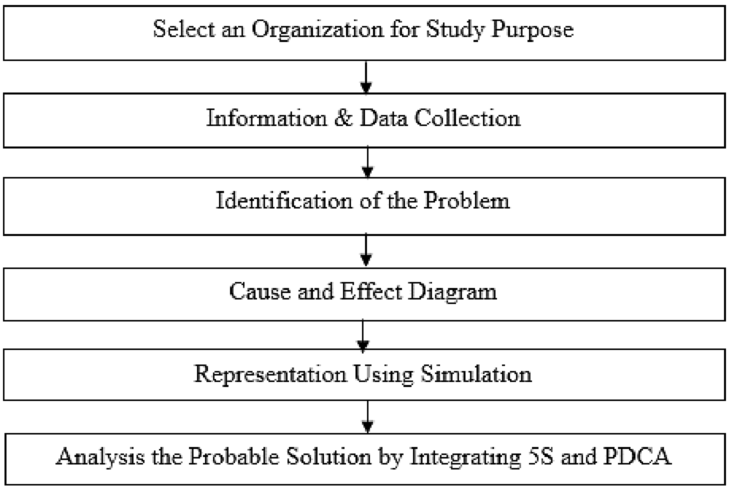


Fig. 1. Research framework.

4.2 | Simulation

An analysis of the suggested model's impact will be done. To reach a conclusion for the case, provide feedback on whether or not the suggested model needs to be improved, and assess the plan's success, the comparative effect obtained in the present model and the proposed model through simulation will be compared. Furthermore, these initiatives will be subject to controlled reviews to sustain achieved gains. Here, two distinct simultaneous parametric types were utilized to measure the aims, and they were as follows.

4.2.1|Graphical simulation using ARENA software

The simulation software program arena offers a comprehensive framework for creating simulation models in various applications. The simulation software program arena provides a comprehensive framework for creating simulation models in a range of applications. The arena user constructs an experiment model by arranging modules—boxes of different shapes—that stand in for processes or logic. Connector lines connect these modules, defining the entities' flow. Modules possess particular activities about entities, flow, and timing; nonetheless, the modeler is ultimately responsible for accurately representing each module and entity concerning actual objects. Work In Process (WIP) levels and cycle times are two examples of statistical data that can be recorded and produced as reports. The following functions are necessary for simulation: modeling, animation, model verification, data analysis for inputs and outputs, analysis results, etc. Our study was performed using this software, and the result is provided.

4.2.2|Numerical simulation using Monte Carlo

A broad class of computing algorithms known as Monte Carlo Methods or Monte Carlo Simulation rely on repeated random sampling to produce numerical results. The fundamental idea is to leverage randomness to find solutions to issues that, in theory, maybe deterministic. They are frequently applied to mathematical and physical problems and are accommodating in situations where other methods would be challenging or impossible. In general, we used the Monte Carlo Simulation to get random output data for our proposed model of each type of defect for different 5 days, where the input data comes from our current model's real-time data. Here, we allocate the random data from the simulation as secondary data that is implementable for our proposed model output. To get random number generation, we need to help with each defect's mean and standard deviation, which we got from our collecting real-time data.

5|Data Collection

First, we selected a particular sewing section of the industry, Silken Sewing Ltd, which was chosen for the initial study. We have selected that sewing section for information & data collection to identify the problem and list what to solve. The infrastructure of the organization is given in *Table 1*.

Table 1. Infrastructure of Silken Sewing Ltd.

Company Name	Silken Sewing Ltd.
Location	Vobanipur, Gazipur, Bangladesh
Product Type	Knit/Woven Garments
Number of Workers	Male: 1800, Female: 600, Total: 2400
Production Capacity	1300000 pcs/year
Working Hour Per Day	10 hours (maximum)
Line in a Production Floor	47
Sewing Machine in a Line	7
Sewing Machine (Observation)	5

In this phase, we've acquired details about the selected factory's specific department for sewing errors. For the analysis portion of the study, we have gathered data on various sewing flaws that the management has provided.

5.1|Steps Involved in Collecting Data

There are some proposed activities and some initial activities in this arrangement. Proposed activities are when the model is implemented while carrying out certain tasks. It highlights the differences between the initial and proposed setup operations flow and the rationalization of the setup activities' constituent parts. The steps involved in the detailed analysis are represented by the flow diagram, which is given in *Fig. 2*.

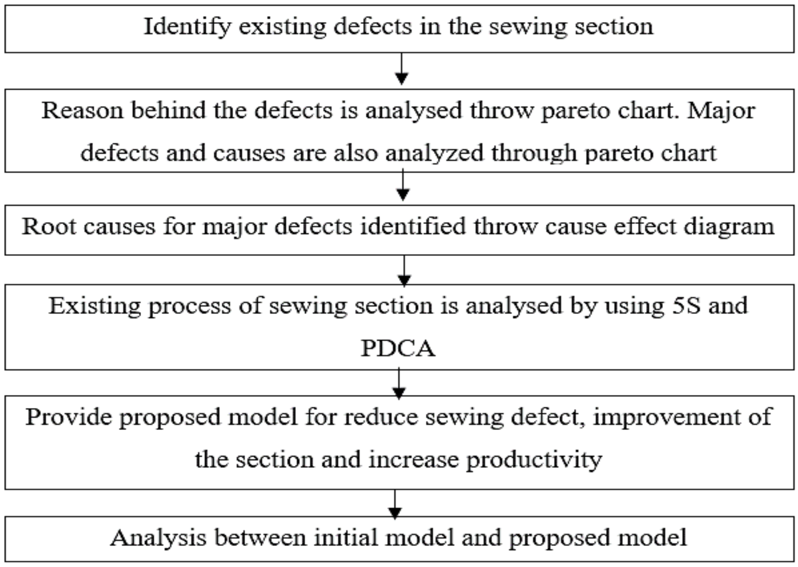


Fig. 2. Flow chart of steps involved in the collecting data.

5.2 | Identification of the Defects

For this particular section, defect areas have been identified. For findings problems and data analysis, we have listed out the sewing defects from our selected factory, which are:

- *Uncut thread.*
- *Skip stitch.*
- *Open seam.*
- *Joint stitch.*
- *Level and size mistake.*
- *Uneven.*
- *Puckering.*
- *Tension.*
- *Needle damage.*
- *Up-down.*
- *Pleat.*
- *Shade.*
- *Sewing reject.*
- *Fabric fault.*
- *Broken stitch.*
- *Dirty spot.*
- *Oil spot.*
- *Raw edge.*

5.3 | Cause and Effect Diagram

Here, brainstorming is done through different levels of management to find out the reason behind the major problem.

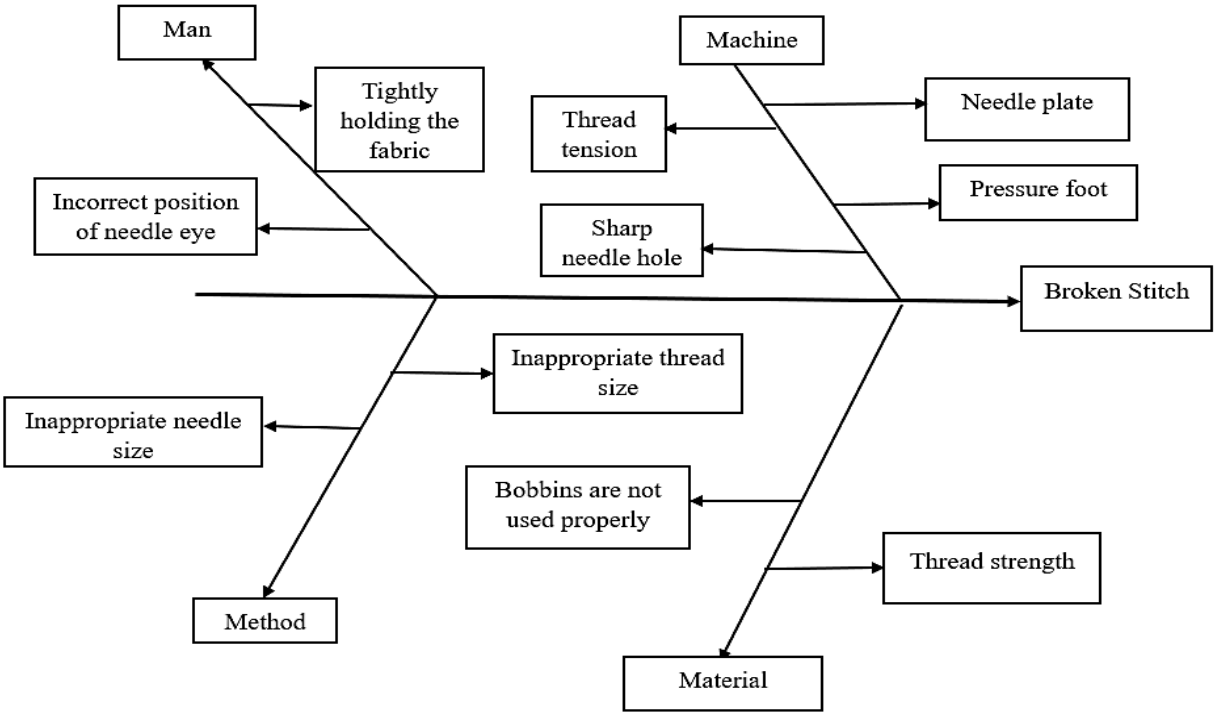


Fig. 3. Cause and effect diagram for broken stitch.

5.3.1 | Cause and effect diagram for broken stitch

A broken stitch can refer to several things depending on the context. In knitting, a broken stitch can occur when a stitch is accidentally dropped off the needle and unravels down the fabric. It can happen if the needle is not inserted correctly into the stitch or the yarn is pulled too tightly. If caught early, a dropped stitch can be picked up and fixed without causing noticeable damage to the fabric. However, a dropped stitch can lead to a hole in the finished piece if left unattended.

In embroidery, a broken stitch can refer to a stitch that has been interrupted or cut short, resulting in a gap in the embroidered design. It can happen if the thread is not pulled through entirely or gets snagged on something while stitching. To fix a broken stitch in embroidery, you can re-thread your needle and work over the gap to fill it in.

5.3.2 | Cause and effect diagram for open seam

An open seam is a knitting or crocheting stitch where the loops are intentionally left unworked, resulting in an open and lacy texture. This technique often creates decorative patterns in clothing or accessories such as shawls, scarves, and blankets. To create an open seam in knitting, you can use yarn overs or drop stitches from the needles to create intentional holes in the fabric. In crocheting, open stitches can be made by working chains or skipping stitches to create spaces between the stitches. Some common examples of open stitches in knitting include lace patterns like feather and fan, while in crocheting, examples include shell stitches and filet crochet.

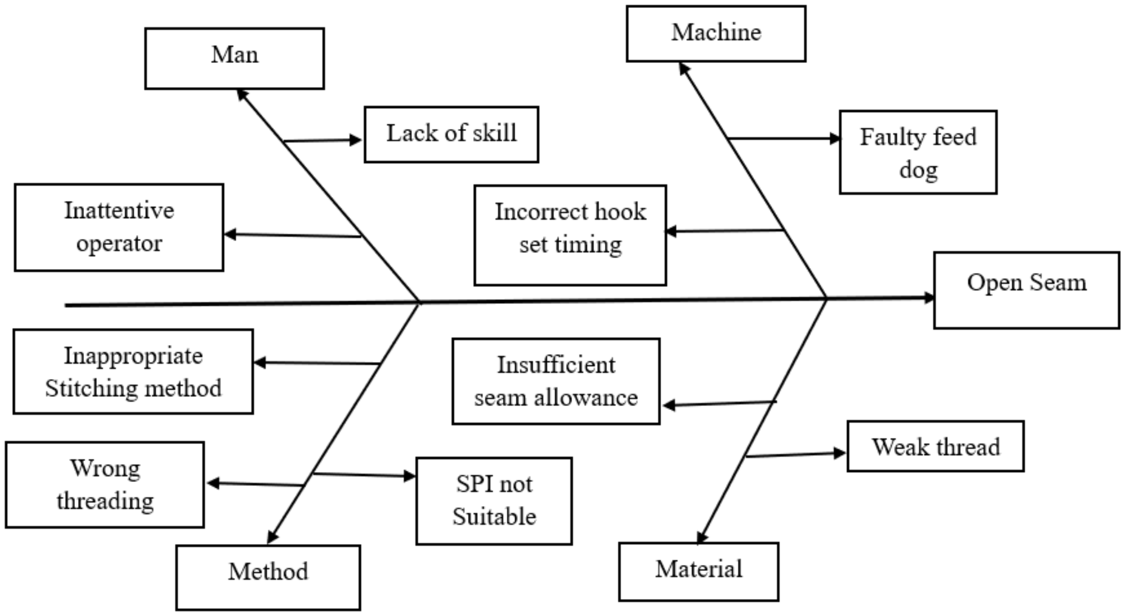


Fig. 4. Cause and effect diagram for open seam.

5.4 | Determination of Probable Solution by Integrating 5S and PDCA

From the top management of the specific company, some probable solution was made that is represented below.

Table 2. Probable solution of major defects.

SL.	Defects Name	Cause	Probable Solution
1	Broken stitch	Incorrect needle size or type, damaged needle, incorrect thread tension, quality, etc.	Choose a needle that is the correct size, inspect the needle regularly for burrs or nicks, replace the needle if it is damaged, adjust the thread tension according to the fabric, and use high-quality thread that is compatible with the fabric.
2	Open seam	Improper stitching technique, incorrect needle size, machine problems, thread path issues, bobbin thread issues, etc.	Use high-quality thread compatible with the fabric, use a needle and thread specifically designed, practice proper sewing technique, use a smooth, even motion, and use the correct type of thread for the bobbin.
3	Raw edge	Incorrect cutting, rough handling, abrasion, exposure to the elements, etc.	Hem the fabric, overlock the fabric, pink the fabric, surging the fabric, fray check.
4	Joint stitch	Incorrect stitch type, improper stitching technique, fabric damage, etc.	Use the correct stitch type, use the proper stitching technique, reinforce the stitches, and protect the stitches.
5	Dirty spot	Oil or grease from the sewing machine, unclean thread, used fabric, etc.	Clean the sewing machine regularly, use clean thread, pre-wash the fabric, use a spot remover, and use a seam ripper.
6	Uncut thread	Improper thread tension, incorrect needle size, bobbin thread issues, etc.	Practice proper sewing techniques, adjust the thread tension, choose the right needle, inspect the needle regularly, and use a thread trimmer.
7	Skip stitch	Incorrect thread tension, needle size, poor fabric quality, machine problems, workers' faults, etc.	Adjust the thread tension, choose the right needle size, inspect the fabric, and practice proper sewing techniques.

5.5 | Mathematical Formulation

Mean of specific types of defects (μ): $\frac{\text{Different days total sum of defect}}{\text{n}}$.

The standard deviation of the defect (σ): $\sqrt{\frac{\sum(x-\mu)^2}{n-1}}$, where, x = each day's specific types of defect, μ = mean of specific types of defect, n = total days defect are counted.

5.6 | Evaluation of Effectiveness

To measure OEE, the parametric indicators are shown in *Table 3*.

Table 3. Parametric indicators of OEE.

Parametric Indicators	Algorithm
Machine availability	$\frac{\text{Run Time}}{\text{Planned Production Time}}$
Machine performance	$\frac{\text{Total Count/Run Time}}{\text{Idle Run Time}}$
Production quality	$\frac{\text{Good Count}}{\text{Total Count}}$
OEE	Availability × Performance × Quality

5.7 | Current Setup Representation

In *Fig. 5*, the current production flow for the sewing line is shown for our selected industry.

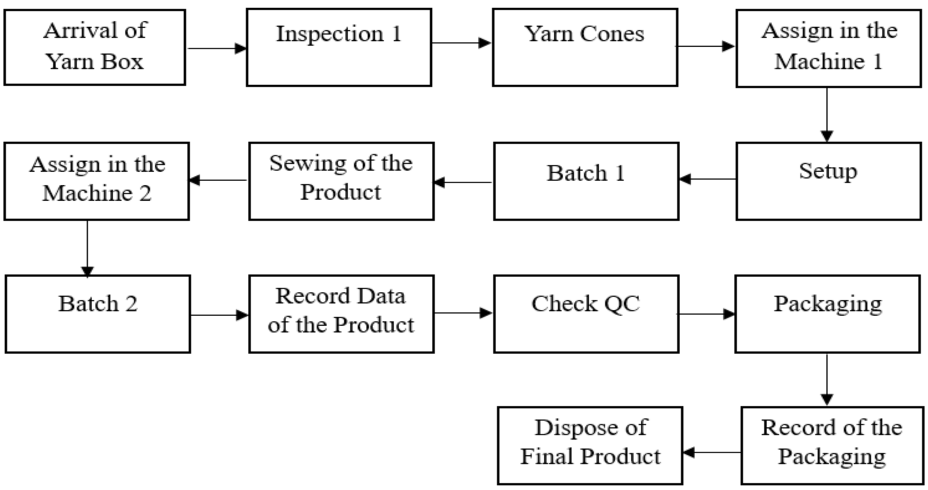


Fig. 5. Setup workflow for current model.

This model describes the current production process of the sewing line. The production line started from the arrival of the yarn box to the disposal of the final products. We are analyzing this workflow, finding out the problem of this line, and trying to fix it for our proposed model.

5.8 | Data Table for Defects

For data collection and analysis, we have collected data from the selected industry, Silken Sewing Limited, for June 2023. *Table 4* shows the summary of data collection.

Table 4. Data table for current defects.

Name of Defects	Day- 1	Day-2	Day-3	Day-4	Day-5	Total Defects Per Item	Percentage of Defects
Uncut thread	6	2	7	5	4	24	4.6%
Skip stitch	2	-	7	6	6	21	4.1%
Open seam	20	28	3	22	18	91	17.6%
Joint stitch	10	-	15	15	14	54	10.4%
Level & size mistake	-	-	-	2	-	2	0.4%
Uneven	-	-	1	-	-	1	0.2%
Puckering	-	-	-	-	-	0	0.0%
Tension	-	-	-	-	-	0	0.0%
Needle damage	-	-	-	1	1	2	0.4%
Up-down	-	8	-	4	-	12	2.3%
Pleat	2	6	-	-	5	13	2.5%
Shade	-	-	-	-	-	0	0.0%
Sewing reject	2	4	1	6	3	16	3.1%
Fabric fault	-	6	1	7	2	16	3.1%
Broken stitch	44	24	19	19	23	129	24.9%
Dirty spot	4	4	15	12	6	41	7.9%
Oil spot	6	-	-	-	2	8	1.5%
Raw edge	9	28	17	9	11	74	14.3%
Other defects	1	8	-	3	2	14	2.7%
Total defects per day	106	118	86	111	97	518	100.0%

5.9 | Simulation for Current Setup

After running the current model in the arena, to analyze this model, we can find out different types of problems and what is lacking in this plan. For the current model, there is only one QC section before packaging. When the product passes from it, if the defect rate of a product is high, it will be rejected as there is no scope for rework. That's why the rejection rate increases.

Again, when the defect rate of a product is low, it passes back a long way to machine 1 for rework, which is time-consuming. We can also measure idle and bottleneck stations here, which are trying to be solved by implementing the 5S method. That's why we give our proposed model to solve these issues and try to fix it and measure the impact of the proposed model effective or not in the next part. The result of the simulation is provided as a supplementary material.

5.10 | Pareto Analysis for Existing Setup

From the data table, we have a follow-up Pareto analysis, which shows the top defects and helps analyze the reason for the top defects, which is demonstrated by the cause-effect diagram.

Here, broken stitch is the most frequent defect, with as much as 24.9% of the total defect. The open seam is the second most frequent defect, accounting for 17.6%. Also, raw edge is 14.3%, joint stitch is 10.4%, dirty spot 7.9%, and many other defects total 24.9%. So, broken stitch open seams are the Vital Few for the range.

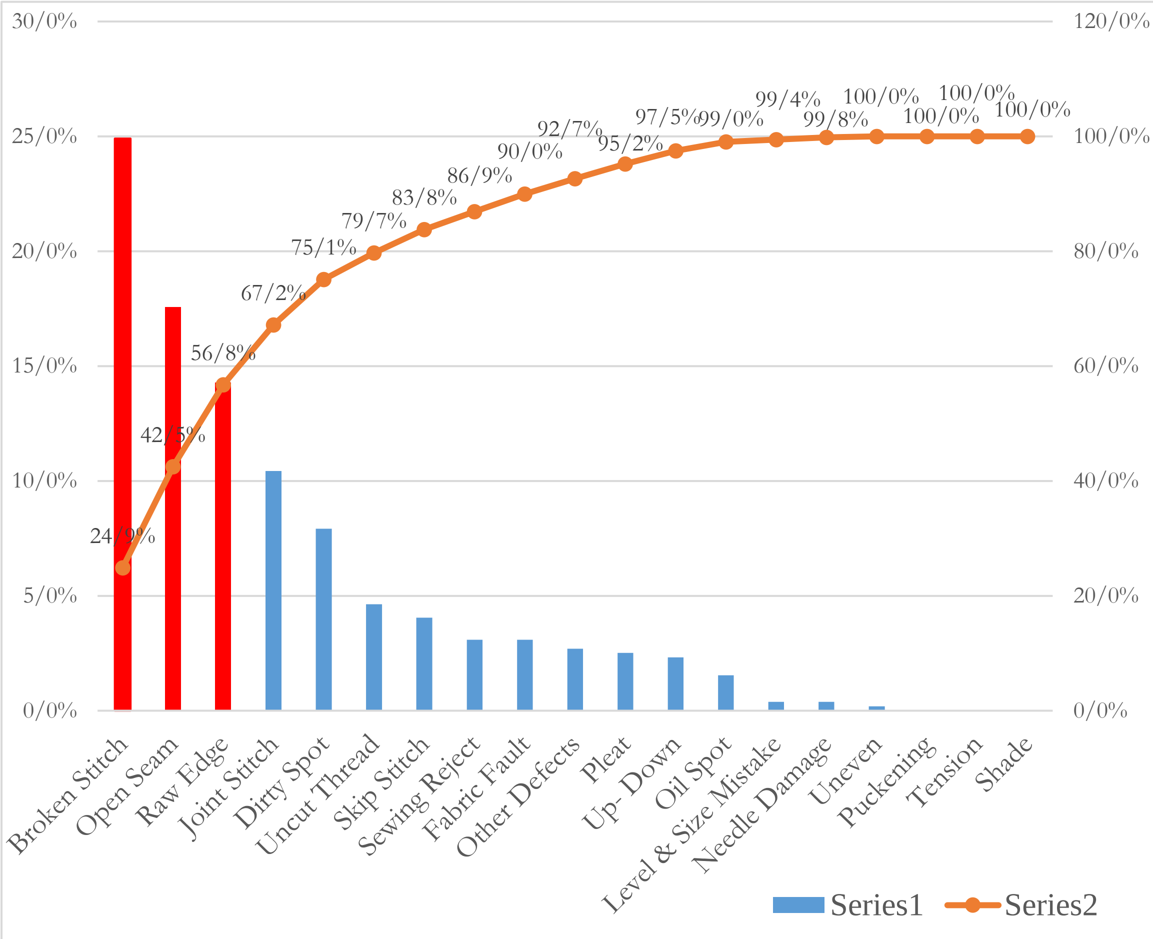
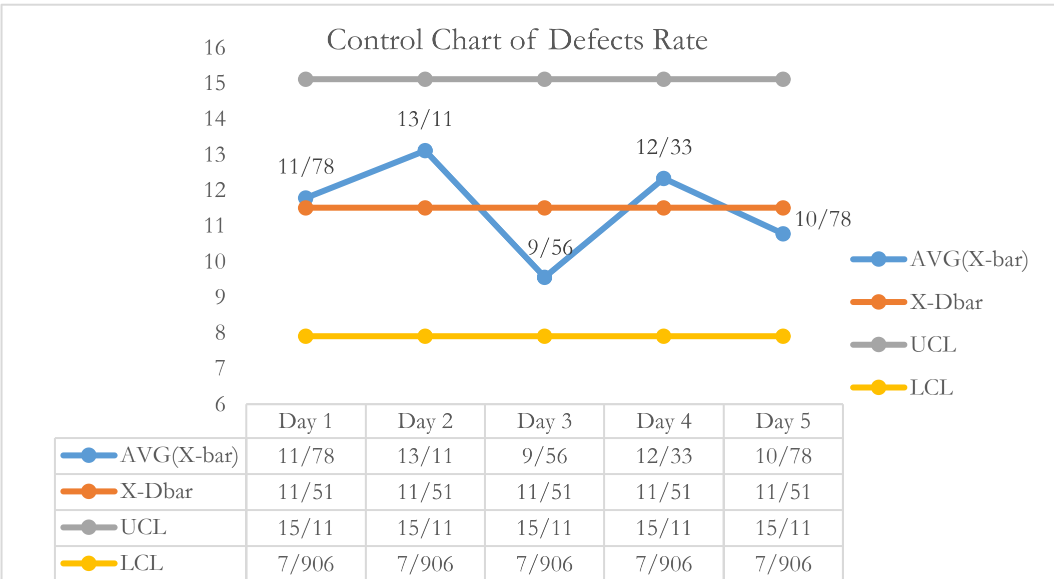


Fig. 6. Pareto analysis of defects.

5.11 | Control Chart for Existing Setup

This control chart analysis is the basis of 5 days of data collection in June 2023. A total of 9 shift defects are evaluated here, which is shown in *Fig. 7*.



	Day 1	Day 2	Day 3	Day 4	Day 5
AVG(X-bar)	11/78	13/11	9/56	12/33	10/78
X-Dbar	11/51	11/51	11/51	11/51	11/51
UCL	15/11	15/11	15/11	15/11	15/11
LCL	7/906	7/906	7/906	7/906	7/906

Fig. 7. Control chart of defects rate.

For this control chart, the graph shows the process is in control. Here, days 1-2-4 are up to CL and 3-5 below CL. The data fluctuates from CL, so the data graph is significant, but the acceptance rate is comparatively low.

6 | Proposed Model Analysis

In *Fig. 8*, the proposed production flow model for the sewing line is shown.

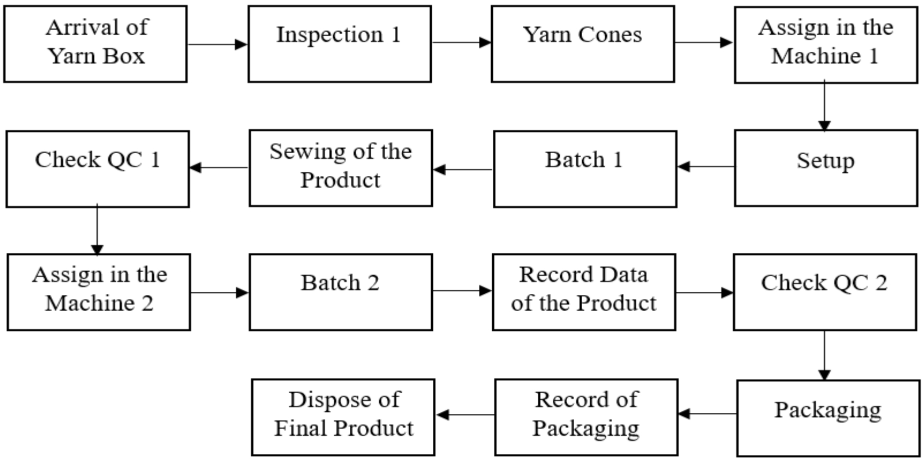


Fig. 8. Setup workflow for proposed model.

This model described the proposed production process in the sewing line, which we developed after analyzing the current model problem. As we work to decrease the defect rate, we added an extra inspection section here, which helps us decrease the defect rate.

6.1 | Data Table after Improvement

Data in *Table 5* shows the defect rate of the sewing line after working on the proposed model in the arena, including an extra quality inspection. These data are simulated data using Monte Carlo simulation based on raw data of the current model.

Table 5. Data table for proposed model.

Name of Defects	Day- 1	Day-2	Day-3	Day-4	Day-5	Total Defects Per Item	Percentage of Defects
Uncut thread	3	1	3	6	4	17	6.2%
Skip stitch	1	-	2	4	7	14	5.1%
Open seam	7	10	9	8	11	45	16.3%
Joint stitch	6	1	-	2	4	13	4.7%
Level & size mistake	-	-	2	2	-	4	1.4%
Uneven	-	-	-	1	-	1	0.4%
Puckening	-	-	-	-	-	0	0.0%
Tension	-	-	-	-	-	0	0.0%
Needle damage	2	-	1	3	-	6	2.2%
Up-down	-	3	2	-	1	6	2.2%
Pleat	1	4	-	-	1	6	2.2%
Shade	2	-	1	3	2	8	2.9%
Sewing reject	5	2	4	4	3	18	6.5%
Fabric fault	-	3	1	-	-	4	1.4%
Broken stitch	20	10	11	12	9	62	22.5%
Dirty spot	2	4	3	5	-	14	5.1%
Oil spot	2	2	3	4	5	16	5.8%
Raw edge	5	12	7	3	4	31	11.2%
Other defects	2	4	-	5	-	11	4.0%
Total defects per day	58	56	49	62	51	276	100.0%

6.2 | Simulation for Proposed Model

To address the issue with the current production line, we set up an additional quality control station before the sewing line. We ran the model in an arena to determine its efficacy. Here, we attempt to create a simulation model of the federal T-shirt sewing line segment as it currently exists. We suggest creating a simulation model for it to produce an output. We ascertain the appropriate order in which the line should operate and pinpoint the main reason for the discrepancy between the developed and actual production ratio. This simulation explains the proposed strategy regarding run duration, defect rate, machine downtime rate, end-day total production, etc.

6.3 | Pareto Analysis after Improvement

From the data in *Table 5*, we followed up on the Pareto analysis, which shows the top defects after implementing the proposed model.

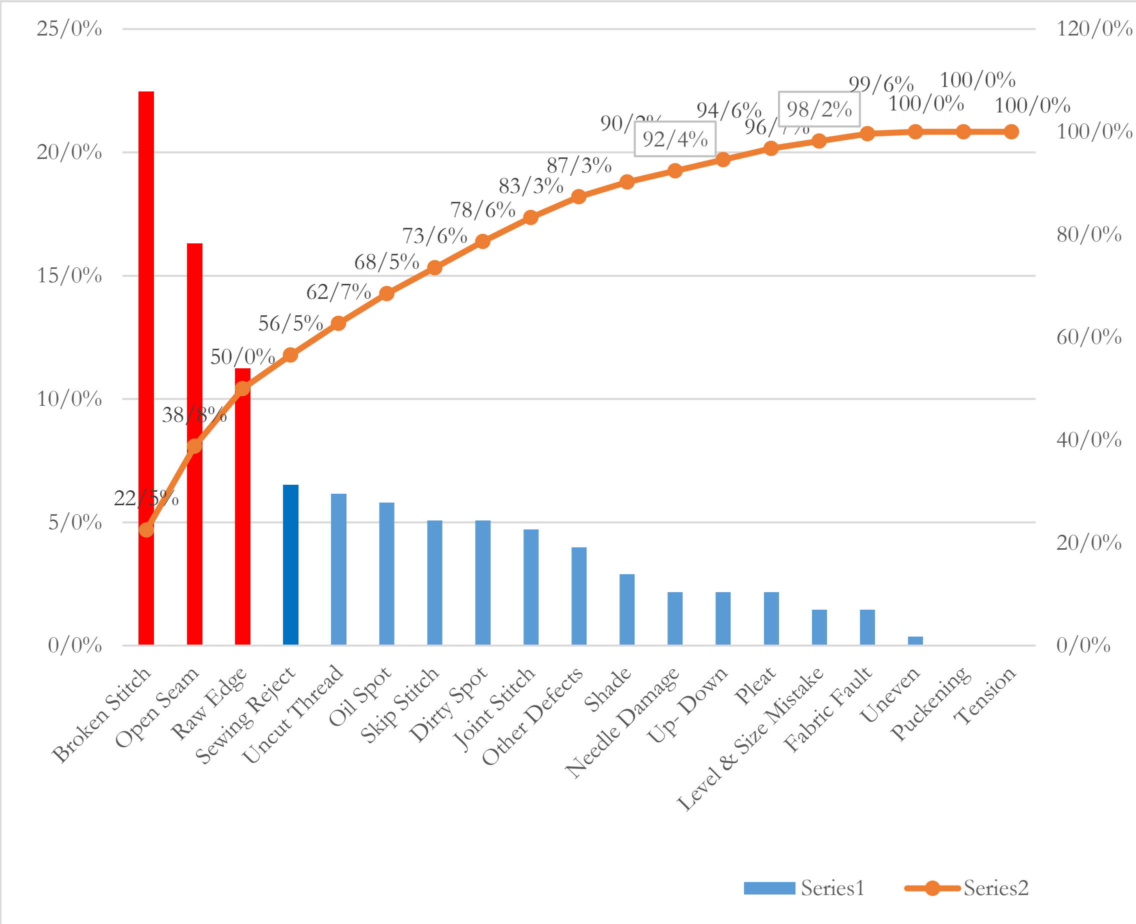


Fig. 9. Pareto analysis of defects for the proposed model.

Here, broken stitch is the most frequent defect, with as much as 22.5% of the total defect. The open seam is the second most frequent defect, accounting for 16.3%. Also, raw edge is 11.2%, sewing reject is 6.5%, uncut thread is 6.2%, and many other defects total 37.3%. So, broken stitches and open seams are also the Vital Few for this range.

6.4 | Control Chart for Proposed Model

This control chart analysis is the basis of another 5 days of data collection after implementing the proposed model. Here, a total of 9 shifts' production defects are evaluated, which is shown in *Fig. 10*.

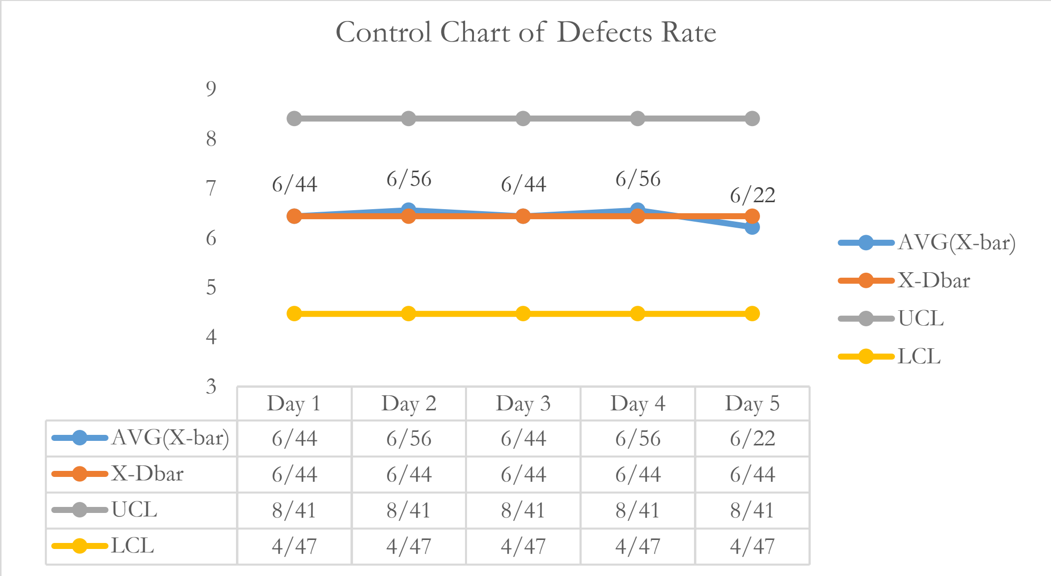


Fig. 10. Control chart of defects rate for the proposed model.

For this control chart, the graph shows the process is in control. Here, days 1-3 are equal to the CL, days 2-4 are up to CL, and days 5 are below CL. The data doesn't fluctuate from CL, which may mean the data graph is significant. Also, the acceptance rate of defects is very high.

7 | Calculation and Result Analysis

5S is a system that enhances productivity, quality, efficiency, and safety while streamlining the work environment and cutting down on waste and pointless activities. The 5S Philosophy emphasizes regular work routines and efficient workplace management in conjunction with the PDCA cycle tool to boost productivity. Plan, do, check, and act are the four pillars of the PDCA cycle, which any organization may use as a foundation for improvement initiatives. Workplace daily operations involve tasks that 5S and PDCA impact; doing them quickly and effectively is critical. It is among the best Lean Manufacturing practices businesses adopt while adopting Lean. People benefit from a better, more enjoyable work environment, increased job satisfaction, and the opportunity to influence how their work is completed and carried out, leading to overall improvements. It boosts customer satisfaction, productivity, product quality, and the company's ability to grow.

Large rating levels for some issues may impact the organization's profitability and production factor. Through analysis, various defect problems can be found, and they should receive the utmost attention to be resolved appropriately. Their cause adequately explained for the ongoing operations and activities. Every item needs to be labeled and stored to make it simple to locate and remove from the factory floor. To minimize downtime costs and enhance quality, it is imperative to maintain a clean and orderly workspace. It includes sweeping floors, cleaning machinery, and ensuring nothing gets done.

7.1 | OEE Calculation

The lines of both models are displayed in this section to illustrate the role of the lean manufacturing tools used in this instance. The first model depicts the circular sewing area's production flow process; however, the suggested model's major modifications and enhancements impact the equipment's overall efficacy. It should be mentioned that the models examine the extra quality check plan that adds value to the product.

7.1.1 | Existing setup model calculations

Table 6 shows observed data for the current production line.

Table 6. Observed data for current production line.

Content	Data
Shift length	9 hours (540 minutes)
Breaks	Tea (15 minutes × 2) = 30 minutes; Lunch (1 hour = 60 minutes)
Downtime	12% of shift
Idle run rate	5 pieces/minute
Total count (avg.)	1878 units
Reject count (avg.)	104 units

Planned Production Time

Planned Production Time is the first step in the OEE computation. First, take out any shift times (usually breaks) during which production is not planned to be operated.

Formula: Plant Operating Time − Planned Shutdown.

Solution: Plant Operating Time = 9 hours × 60 = 540 Minutes.

Planned Shutdown = Tea Break + Lunch Break = (10×2) + 60 Minutes = 80 Minutes.

Planned Production Time = 540 Minutes − 80 Minutes = 460 Minutes.

Run Time

The time that production was genuinely running (i.e., not halted) must then be determined. Don't forget that stop times should account for scheduled and unscheduled stops (such as breakdowns and changeovers). They both offer room for development.

Formula: Planned Production Time − Downtime Loss.

Solution: Downtime Loss = 12% of 540 Minutes = 65 Minutes.

Run Time = 460 Minutes − 65 Minutes = 395 Minutes.

Good Count

It must also be computed if the good count is not explicitly tracked.

Formula: Total Count (Avg.)− Reject Count (Avg.).

Solution: 1878 pieces − 104 pieces = 1774 pieces.

Availability

The first of the three OEE factors to be determined is availability. It considers both planned and unplanned stops in the process's operation.

Formula: Run Time/Planned Production Time.

Solution: 395 Minutes/460 Minutes = 0.85 (85%).

Performance

Performance comes in second out of the three OEE factors that must be computed. It considers instances where the process (brief halt and slow cycles) operates below its maximum potential speed.

Formula: (Total Count/Run Time) / Idle Run Rate.

Solution: (1878 pieces/395 Minutes) / 5 pieces per minute = 0.95 (95%).

Quality

The final OEE factor that needs to be determined is quality. It takes into consideration produced items that fall short of quality requirements.

Formula: Good Count/Total Count.

Solution: 1774 pieces / 1878 pieces = 0.94 (94%).

OEE

Finally, the three OEE components are multiplied to determine OEE.

Formula: Availability × Performance × Quality.

Solution: 0.85 × 0.95 × 0.94 = 0.75 (75%).

7.1.2 | Proposed model calculation

Table 7 shows observed data for the proposed production line.

Table 7. Observed data for proposed production line.

Content	Data
Shift length	9 hours (540 minutes)
Breaks	Tea (15 minutes × 2) = 30 minutes; Lunch (1 hour = 60 minutes)
Downtime	10% of shift
Idle run rate	5 pieces/minute
Total count (avg.)	1836 units
Reject count (avg.)	55 units

After implementing 5S and developing our proposed model, downtime losses will decrease to 10%.

Run Time

Formula: Planned Production Time − Downtime Loss.

Solution: Downtime Loss = 10% of 540 Minutes = 54 Minutes.

Run Time = 460 Minutes − 54 Minutes = 406 Minutes.

Good Count

Formula: Total Count (Avg.) − Reject Count (Avg.).

Solution: 1836 pieces − 55 pieces = 1781 pieces.

Now, for the proposed plan.

Availability

Formula: Run Time / Planned Production Time.

Solution: 406 Minutes / 460 Minutes = 0.89 (89%)

Performance

Formula: (Total Count / Run Time) / Idle Run Rate.

Solution: (1836 pieces / 406 Minutes) / 5 pieces per minute = 0.90 (90%).

Quality

Formula: Good Count / Total Count.

Solution: 1781 pieces / 1836 pieces = 0.98 (98%).

OEE

Formula: Availability × Performance × Quality.

Solution: 0.89 × 0.90 × 0.98 = 0.78 (78%).

7.2|Comparative Result

The results are given quantitatively in this chapter. After comparison, the first and the suggested models used the data gathered from the circular area's production process. *Table 5* shows that even with an OEE variance of ±3%, scenarios that do not differ considerably in terms of what data should be collected for both the model and its comparison are still obtained. As a result, while utilizing historical process data, the system is guaranteed to maintain an identical sewing line production flow for all situations. Regarding the indicators, they do not overlap, indicating a notable distinction between the enhanced model and the existing one.

Table 8 shows the detailed OEE performance for the initial model and proposed model comparison.

Table 8. Parametric indicators comparison.

Parametric Indicators	Current	Proposed
Machine Availability	85%	89%
Machine Performance	95%	90%
Production Quality	94%	98%
OEE	75%	78%

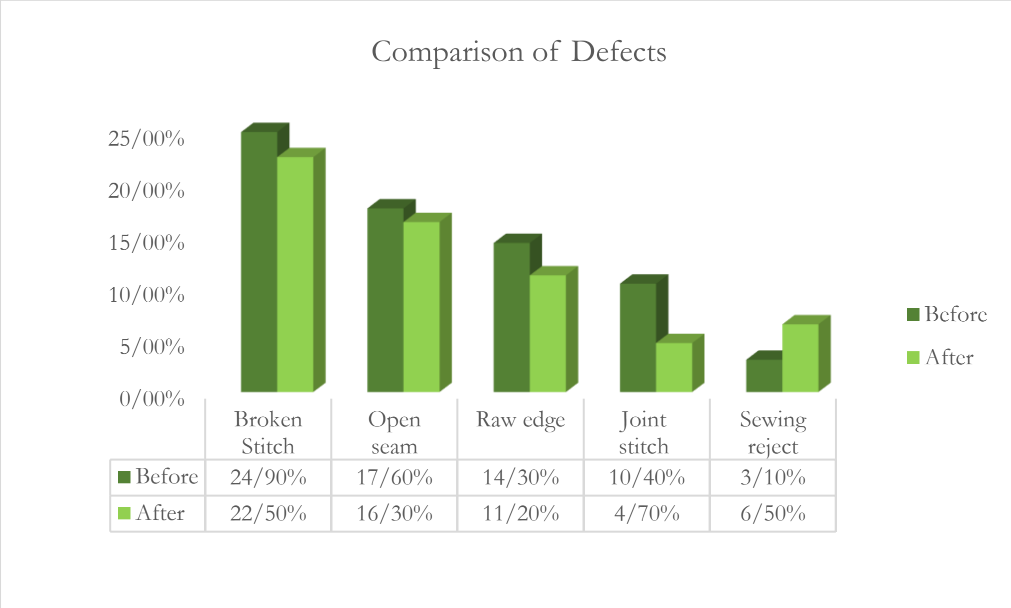
7.2.1|Comparison between before improvement and after improvement

We selected an industry for data collection and visited a particular sewing line for 5 days. Those data reveal significant defects in the sewing line, and we can analyze the reason behind the defects. There was only one quality inspection for the initial production workflow before packaging the final product. After examining the raw data, we can determine if we should add another quality inspection after the sewing product's defect decreases prominently. If we look at the raw data table, we can see that broken stitches and open seams are the vital few of the root causes of significant defects, with percentages of 24.9% and 17.60%. Then, we analyze the root cause of those defects using an effect diagram and find a probable solution. 5S and PDCA lean tools help us to find solutions where PDCA pillars analyze the reason for the defect and provide us with how to solve this problem. That's why we build up our proposed model. Also, the raw data of the control chart shows the significance of defects per day, which fluctuates on the benchmark of the canter line. After getting that information, we developed our proposed model, which included extra quality checking. Implementing those proposed models, we can see the possible improvement of a production line, which decreases the defect rate in a ratio of previous production lines. Analyzing the defect rate, we see significant defects, like the broken stitch percentage, 22.5%, and the open seam percentage, 16.3%. So, preliminary progress is shown. Here, the vital few are also the same as previously mentioned. However, if we look at the control chart, the significance of the defects is more promising than that of the initial model. Let us see the progress rate of the defect rate shown in *Fig. 11*.

This chart comparatively shows before and after the defect rate. We can see that for top major defects, broken stitches, open seams, raw edges, and joint stitches are decreased and developed after implementing our proposed model. Also, here is the comparison of sewing defects; we can see they will be increased for our proposed model. The reason behind the increased sewing rejection was to add an extra quality check in the production line. Initially, this rate is high, which impacts production flow and OEE.

Before implementing the 5S for the initial model, the downtime was 12% of the shift. The reason behind the downtime was not maintenance on the machine on a routine basis, material shortage and quality problems, operating errors, utility disruptions, hazardous workplace, etc., which was a solution by implementing 5S. Production flow downtime decreased by 10% of the sheet for our proposed model. For the initial model, our average production was 1878 units, and the average rejection unit was 104 units for our selected industry, which runs by nine shifts and a shift base target at the end of the day 2700 units. So, the production rate was

70% per day target, and the defect rate was 5.5%. For our proposed model, the production rate might have to increase as downtime decreases. However, the production rate was comparatively slow for extra-quality inspections in the sewing line; reworking those defective products was another reason. That's why, in the defect comparison, sewing rejection increased. For the proposed model, the average production was 1836 units with a production rate of 68% per day target, which decreased by 2% compared to the initial model. Also, the average rejection unit was 55, which is 3% of total production.



	Broken Stitch	Open seam	Raw edge	Joint stitch	Sewing reject
Before	24/90%	17/60%	14/30%	10/40%	3/10%
After	22/50%	16/30%	11/20%	4/70%	6/50%

Fig. 11. Comparison of defects.

Here, we reduced the defect rate from 5.5% to 3%. To analyze the OEE comparative result, the availability of the current plan is 85%, which was increased for the proposed model to 89%. For machine performance, the current plan was 95%, which decreased for the proposed model to 90%, and production quality for the current plan was 94%, which was increased for the proposed model to 98%. Calculating the OEE, we see for the current plan, it was 75%, and for the proposed plan, it was 78%. Initially, OEE increased by 3%, our ultimate target, and we can successfully implement it. The defect rate was minimized, as shown in the previous graphical representations. All the results were validated by comparison for all the parameters evaluated.

8 | Discussion

The production rate, defect rate, and overall efficiency were among the parameters that were appropriately assessed and validated in this study. A comparison and further graphical representation were included with the offered study answer. Manually collected data was obtained straight from the manufacturing floor. Therefore, inevitable mistakes may be discovered in the data. Additionally, some of the computation was done by hand. Thus, there are several errors in that section as well. However, the study's final result was also discovered and included in the analysis. The efficiency of this study may be increased in a number of ways, as well as in other technological methods, as shown in the following sections.

9 | Conclusion

This case study research has examined the sewing department of the chosen clothing sector in terms of efficiency and quality. Using lean techniques and technologies to optimize production processes on a sewing line will, over time, lead to continual improvement in terms of operational efficiency. The activities aim to enhance overall performance using the PDCA and 5S tools. With improved 5S techniques, the PDCA cycle was developed for current system throughput development. Improvements in 5S and PDCA clearly and directly impact production line performance, as demonstrated by the methods developed and applied in this study. Thus, it lends credence to the theory that lean techniques enhance the performance of production systems, which is frequently put forth in the literature. The approach exhibits gain in various system areas in addition to throughput. For instance, the impact of the 5S element, which is arranged in a lean manner, can be observed in other lean practices, including the time spent on defect reduction or the standardization of setup and repair tasks. Various waste kinds were found before the 5S analysis, and the causes of each waste type were examined. The investigation results demonstrate that waste is typically the result of human resources. The sewing floor is determined to have many extraneous items, such as excess baskets, trolleys, inventory backlogs, etc., according to 5S analysis. Items aren't always stored right away after being used. Sometimes, constraints on height and quantity are not appropriately indicated. Stated differently, it is possible to determine how modifications to lean practices affect other parts of lean. Organizations are better equipped to focus on the essential elements of lean with this kind of information. The approach can predict the results of deliberate changes in lean behavior. Because the PDCA cycle and 5S could replicate reality, the company was able to decide whether or not to make improvements.

9.1|Limitations and Future Scope

All in all, integrating the 5S and PDCA techniques substantially benefited the process of reducing sewing defects in the garments sector; yet, the endeavor was not without many challenges. The limitations and future scope of the research procedure are as follows:

I. As the primary technique for lowering sewing defects in the production line, the study team integrated the 5S and PDCA methods. The research team finds that using only one or both of them in conjunction with other lean technologies will increase their effectiveness even further, which was a significant limitation in this study.

II. The research team's exclusive emphasis was the garments industry's T-shirt segment. The research team identified several regions that showed promise and that, had the procedure been used, it would have produced better results.

Despite certain restrictions, this research proved to be very successful in accomplishing its goals. The findings show that the OEE and reduced sewing defects significantly improved.

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Declaration of Interest Statement

The authors report there are no competing interests to declare.

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