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PERFORMANCE OPTIMIZATION OF PILLOW SHEET SET SEWING ASSEMBLY LINE BY SAM ANALYSIS AND LEAN MANUFACTURING TECHNIQUES OF METHOD STUDY & WORK MEASUREMENT

Abdul Haseeb [a1], Muhammad Ali Khan [a2,*], Shakeel Ahmed Shaikh[a3], Zohaib Iftikhar[a4], Ramesh Kumar [a5], Karim Bux [a6], Arshia Naz[d1], Hassam[d2]

[a]Industrial Engineering & Management, Mehran UET, Jamshoro, Sindh, Pakistan.

[b]Yunus Textile Mills (YTM) Limited, Karachi, Sindh, Pakistan.

[a2] muhammad.nagar@faculty.muet.edu.pk

Abstract:

This research was conducted to enhance the productivity of the targeted sewing line at the ABC textile company. The existing SAMs, the capacity of the sewing line for various operations, and several required machines were collected. Moreover, the obtained figures were observed and analyzed by using time study and motion study, and certain improvements were made at the sewing line. Results indicated that SAMs for operations A and B were minimized by -13.64% and -14.54% respectively; whereas, SAM for operation C was increased by 16.67%. Machine requirement for operation C was increased by 100%; moreover, the capacity for operations A, B, and C was increased by 12%, 12.69%, and 40% respectively. When it is to production activities, the little improvements play a significant role in boosting the productivity of the production system. Optimal allocation of human resources, machines, and time are the benefits of line balancing. This can be made possible with the application of the line-balancing framework. With every passing day, the nature and type of article vary at the sewing line thus it is highly needed for the company to get the model developed for an automated line balancing application. Moreover, this work can be extended by the development of a line-balancing framework considering the nature of production.

Keywords: assembly line balancing; performance; lean manufacturing; work measurement; textile.

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1. Introduction

One of the oldest, biggest, and most labor-intensive sectors in the world is the garment sector; in emerging countries, it is the most trustworthy industry in terms of export-based industrialization (Bongomin et al., 2020b). Due to the introduction of new technologies, companies are significantly required to optimize their processes (Arain et al., 2020; Chaudhry et al., 2021; Kalwar et al., 2020, 2022; Khan, Kalwar, et al., 2021). Because of the fierce competition in every business nowadays, the production strategy needs to be enhanced (Kathem et al., 2021). Organizations are continuously searching for ways of productivity improvement and besides other tools, researchers also support lean manufacturing (LM) tools for it (Iftikhar, Kumar, et al., 2022). The structure of clothing has advanced over the past 150 years, moving from manual fitting through automated assembly and occasionally, robotic batch production (Haque et al., 2018). The garment industry has a strict policy that prioritizes the application of contemporary technology (Shakib et al., 2014).

An assembly line is described as a collection of workstations used to construct a product (Rada-Vilela et al., 2013). One of the operations management techniques for streamlining workload issues and enhancing line effectiveness is the assembly line balance (ALB) methodology (Haque et al., 2018). Assembly lines are used to depict the last stage of manufacturing processes and are indicated to a particular flow-based production system (Çil et al., 2020). ALB issue assigns jobs to a group of workstations while imposing specific restrictions, such as cycle duration and precedence restrictions (Sikora et al., 2017; Çil et al., 2020). The goal of optimization techniques is to reduce the costs of assembly-line production (Sikora et al., 2017). According to the literature, ALB and sequencing are among the most difficult tasks (Fani et al., 2020). The ability to effectively and efficiently employ resources through the use of relevant industrial engineering techniques, such as line balance and time study, is significantly associated with contemporary competitiveness in the apparel industry (Bongomin et al., 2020b). Line balancing seeks to reduce the number of workstations and increase production effectiveness (Manaye, 2019).

The sewing process is the most critical stage in businesses that produce clothing since it requires setting up multiple workstations in a specific order to carryout

*Corresponding author: Muhammad Ali Khan, muhammad.nagar@faculty.muet.edu.pk

ordered activities. Making the arrangements or putting the activities in the proper order is a difficult process (Mulani et al., 2019). Instead of spending a large amount of money on the purchase of machinery, the industrial engineering technique makes productivity improvement easier (Mekala et al., 2021). Due to unevenly timed tasks at different stations, work is delayed which results in additional expenses. Companies, especially small and medium-sized businesses are in severe need of working time measuring (Budiman et al., 2019). This is the rationale for shop floor managers' consideration to balance the line by assembly tasks with equal cycle times for the various workstations (Aung & Tun, 2019). In order to complete the entire production within the cycle time, each workstation is given a specific duty, and each workpiece completes the workstation. The assembly line system was created to take advantage of each worker's knowledge to boost productivity and cut cycle time (Xie et al., 2021). However, despite being a subject that has been studied for more than a century, line balancing continues to be of interest to researchers since it is directly related to production effectiveness. To increase and maintain the efficiency of the line, an improved way of balancing assembly lines must be found (Bongomin et al., 2020).

2. Literature Review

Assembly lines have great applications in industry to assemble standardized products due to higher efficiency (Li et al., 2021).Assembly lines are usually designed for the production of standardized products (Andreu-Casas et al., 2022). Assembly ine balancing's primary goals are to either shorten cycle times or deploy fewer workstations (Mulani et al., 2019). According to Germanes et al. (2017), line balancing occurs "when everyone is cooperating in a balanced manner" (Germanes et al., 2017). The literature on the subject of assembly line balance has been authored by several researchers. Lean principles and a line balancing strategy were utilized by Kathem et al. (2021) to reduce lead times and non-value-added operations and boost production in the footwear sector. In the study, Rockwell arena software was employed. Results showed that non-value-added tasks were decreased by 36%, production cycle time was shortened by 31%, and productivity rose by 43% (Kathem et al., 2021). Besides the tasks fixed allocated to stations, some tasks can be shared between adjacent stations (Schlüter & Ostermeier, 2022). There are various types of assembly lines i.e. straight-shaped assembly line (SSAL), parallel workstation assembly line (PWAL), U-shaped assembly line (U-Line), two-sided assembly line (2SAL), parallel assembly line (PAL), multi-manned assembly line (MAL), and hybrid assembly line (HL) as represented in Figure 1.

Rajput et al. (2020) conducted the case study at the production line of Automobile Industry to investigate the productivity (Rajput et al., 2020). The annual data is collected from Pre-treatment Electrode Deposition Line (PT-ED Line). Takt Time in one of the process of PT-ED Line of paint shop is reduced from 2.04 min to 1.78 min. This is done with the help of electrodes replacement and increasing of amperes of the electrodes in the Cathode Electrode Deposition (CED) process. This reduction in takt time increased the daily production of paint shop from 245 units to 280 units (Rajput et al., 2020). Kumar et al. (2020) conducted the case study at the assembly & production line of Automobile Industry to investigate the productivity (S. Kumar et al., 2020). Line balancing, time & motion study and OEE were used and existing OEE is calculated, compared with world class OEE, gap is identified and corrective measures were suggested to minimize the gap. Three OEE losses i.e. downtime, speed loss and quality loss are measured and the responsible factors behind these losses are identified (S. Kumar et al., 2020). Khan et al. (2020) conducted the systematic review of lean manufacturing practices about the assembly &production lines of Automobile Industry (Khan et al., 2020). Iftikhar et al. (2022) conducted the case study at the textile stitching unit to improve the productivity. The track of flat sheet stitching assembly line with low productivity was selected as the case and production data was collected. Lean techniques of line balancing and time & motion study were applied for work simplification. The sorted data was collected, tabulated, analysed and presented. The number of machines were reduced from 14 to 10 (1 in operation A and 3 in operation B); SAMs were reduced from 1.5 to 1.053 minutes (16.20% reduction in SAM of operation A and 36.60% in the SAM of operation B); working time was reduced from 40250 to 19180 minutes (reduction of 32.96% of the manpower time in operation A and 57.73% of the time in operation B) (Iftikhar, Khan, et al., 2022).

Line balancing, frequent time & motion study, periodic takt time, TPM programs and OEE were also suggested

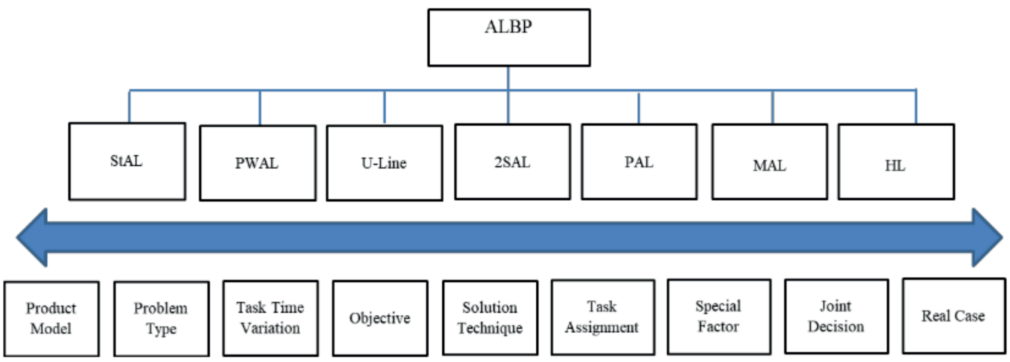

Figure 1: Classification of assembly line balancing problem (Source: (Chutima, 2020)).

among the other lean manufacturing practices for the improvement in productivity, profitability and quality of the assembly and production lines of Automobile Industry (S. Kumar et al., 2020; Rajput et al., 2020). Sahito et al. (2020) conducted the case study on the assembly line of pharmaceutical to evaluate the productivity and investigation of lean manufacturing wastes (Sahito et al., 2020). The major causes of the identified lean wastes were identified by the detailed analyses with Ishikawa diagram. The defect waste, motion waste, waiting waste and over processing waste are identified as the most deadly wastes at the selected production line. The activities which created the wastes are identified and measured. The corrective actions are suggested for the reduction or elimination of the identified lean wastes (Sahito et al., 2020). Khan et al. (2020) conducted the systematic review of lean manufacturing practices in Pharmaceutical Industry (Khan, Shaikh, & Marri, 2020). Line balancing and frequent time & motion study were found popular and suitable among the other lean manufacturing practices for the improvement in productivity, profitability and quality of assembly & production lines of pharmaceutical industry (Sahito et al., 2020; Shar et al., 2021). Kumar et al. (2022) conducted the case study at the textile stitching unit to improve the productivity. The track of fitted sheet stitching assembly line with low productivity was selected as the case and production data was collected. Lean techniques of line balancing and time & motion study were applied for work simplification. The sorted data was collected, tabulated, analysed and presented. SAMs for the operation A and B were minimized by 26.67% and 4.42%; machine requirement for operation A was also minimized by 16.67%; moreover, the capacity was increased by 24.24% for operation A and was decreased for operation B by -27.85% (R. Kumar et al., 2022).

Haque et al. (2018) used the ABL technique in their research and proposed a new sewing scheme, which resulted in a decrease in the amount of labor needed from 20 to 18. Additionally, it was said that the overall cost may rise from 144000 to 16000tk per month if the labor cost were to be 8000tk per month. An increase of 129 to 235 pieces per hour (22048 pieces per month) could result from this improvement (Haque et al., 2018). Lakho et al. (2021) conducted the case study on the production line of heavy engineering industry to evaluate the productivity (Lakho et al., 2021). Line balancing, time & motion study, Overall Equipment Effectiveness (OEE), TPM & 5S were used to evaluate & analyse the productivity and overall performance. The data of six (6) months was analyzed in MS excel and Minitab. The realignment of housekeeping activities was proposed which can reduce the delay by 33% (Lakho et al., 2021). Shar et al. (2021) conducted the case study at the production line of large pharmaceutical company to evaluate the productivity (Shar et al., 2021). The data is gathered from the working plant and analysed by fish bone diagram to find out the potential causes. Pareto chart was used to priorities the problem and descriptive analysis was conducted. The lean tools of TPM, OEE were implemented and and causes were identified. The overall performance of the production line was increased by 11% by the proposed solutions (Shar et al., 2021). Line balancing, time & motion study, 5 whys, 5S, cause & effect analysis were also recommended as the essential tools with TPM & OEE for the improvement in productivity, profitability and quality in the assembly & production line of manufacturing industry (Shar et al., 2021; Lakho et al., 2020).

Manaye (2019) used two optimization techniques. To determine the optimal line balancing method, he thoroughly reviewed the literature. To redistribute the workload among the operators and improve the accuracy of standard time, line balancing techniques were adopted. Finally, the takt time, cycle time, and various workstations were taken into consideration (Manaye, 2019). It is observed that unlike the other developed countries, very few studies are conducted to explore the potential of lean manufacturing practices in the Pakistani Industry. the applications of these lean manufacturing practices in the Pakistani Industry are discussed with the help of suitable examples and related case studies (Khan et al., 2020). Line balancing, time & motion study were also recommended as the essential tools with other lean tools i.e. Six Sigma (DMAIC), Lean Six Sigma (LSS) and Value Stream Mapping (VSM) for the improvement in productivity, profitability and quality in the assembly & production lines of various manufacturing industries (Khan, Shaikh, Lakho, et al., 2020; P. Kumar et al., 2020; Zaidi et al., 2021). There are many notable benefits and applications of Six Sigma (DMAIC) and Lean Six Sigma (LSS) in the productivity improvement of assembly & production lines of various manufacturing industries (P. Kumar et al., 2020; Mughal et al., 2020). Many new case studies and applied researches discussed the benefits and applications lean tool of Value Stream Mapping (VSM) in the productivity improvement of various assembly lines and production lines (Khan, Shaikh, Lakho, et al., 2020). There is the great potential for the implementation of lean manufacturing practices for the productivity improvement in the assembly & production lines of Pakistani Industry (Khan et al., 2020).

Aung and Tun enhanced Oman's pencil skirt manufacturing process (2021). The efficiency of the single model assembly line was increased by the decrease of value-added activities, balanced workload, and cycle time at each of the workstations through line balancing. Two methods were employed to increase productivity; work-sharing among workstations performing comparable tasks and providing the necessary training and oversight for sewing operations (Aung & Tun, 2019). Buksh et al. (2021) conducted the case study at the production line of textile manufacturing unit. Line balancing, time & motion study, standardization, 5S and SMED were implemented in the selected case area of flatbed printing machine (Bukhsh et al., 2021). The changeover time was reduced from 142 minutes to 117 minutes which in turn increased the overall productivity of flatbed printing machine (Bukhsh et al., 2021). Few recent researchers and practitioners have discussed the applications of lean practices to productivity improvement in the production lines of textile industries by (Khan, Marri, & Khatri, 2020a; Khan et al., 2020). Khan et al. (2021) explored the applications of Waste Relations Matrix (WRM) in the identification of seven deadly wastes of lean manufacturing in the production lines (Khan, Khatri, et al., 2021a). The case study of textile production line was also discussed about the investigation of seven Lean Manufacturing wastes i.e. overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion and defect. The wastes were investigated and suggestion were proposed (Khan, Khatri, et al., 2021a). The line balancing, time & motion study, WRM, Andon, root cause analysis, SMED and 5S were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry (Bukhsh et al., 2021; Khan, Khatri, et al., 2021a).

Zaidi et al. (2021) reviewed the benefits & applications of lean manufacturing practices from eight (8) diverse assembly and production lines of various industries (Zaidi et al., 2021). Khan et al. (2018) conducted the case study at production line of textile industry of Pakistan where productivity, profitability and quality was investigated (Khan, 2018; Khan, Khatri, et al., 2021b). The yarn manufacturing process of ring spinning consisted of six manufacturing processes. i.e. Blow room, Carding, Drawing, Combing, Roving, Ring and Winding were the focus of the study. The data is collected and defects were identified, analysed and investigated. The causes were identified and suggestion were proposed (Khan, 2018; Khan, Khatri, et al., 2021b). The line balancing, time & motion study, root cause analysis, six sigma (DMAIC), lean six sigma (LSS), TPM and OEE were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry (Khan, 2018; Khan, Khatri, et al., 2021b). A narrative literature review was conducted about six (6) diverse manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry. Twenty Nine (29) LM tools were identified from review to improve the productivity of the assembly lines (Iftikhar, Kumar, et al., 2022).

Iftikhar et al. (2021) initiated the industrial project in the collaboration of Yunus Textile Mills with the aim to increase the productivity to increase the production capacity at the company. Initially non-value added (NVA) activities were found as the major cause of unbalanced lines, increased waiting time, unnecessary movement and derangement of machines. The problem of reducing and/or eliminating (NVA) activities was sorted with lean techniques of line balancing, time & motion study, cellular manufacturing and bottleneck analysis. Removal of (NVA) activities, reduction in idle time, availability of accessories and elimination of bottleneck improved the overall productivity. This further resulted in substantially reduced number of machines, SAMs and working time of the low productivity tracks at textile stitching unit throughout from stitching to checking and checking to packing section (Iftikhar et al., 2021). Mughal et al. (2021) conducted the case study at the production line of textile stitiching unit where productivity, profitability and quality was investigated (Mughal et al., 2021). Pareto charts and Fish bone diagrams were used to analyze the defects and skip stitch and stain spot are identified as the most frequent defects. The causes were identified and suggestion were proposed (Mughal et al., 2021). The authors presented the conducted case study at the production line of textile industry to investigate the seven Lean Manufacturing wastes only i.e. overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion and defect (Khan, 2018; Khan, Marri, & Khatri, 2020b). The lean wastes are identified, investigated and suggestion were proposed (Khan, 2018; Khan, Marri, & Khatri, 2020b). The line balancing, time & motion study, Andon, jidoka, poka yoke, standardized work, root cause analysis, six sigma (DMAIC) and lean six sigma (LSS) were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry (Khan, 2018; Khan, Marri, & Khatri, 2020b).

Yemani A. (2021) used control limit analysis (CLA) and discrete event simulation on an assembly line to address line balancing (LB) of the BOB T-shirt model (DES). Bottleneck procedures on the assembly line were first discovered by the author using CLA, and then the LB technique was applied to increase the productivity of the model sewing line. The BOB T-shirt model consisted of 16 operations, hence the average minute values for each operation were subtracted. Major bottleneck operations were examined using CLA and DES. Bottlenecks of the sewing section were defined as such operations with SMV less than the lower control limit and greater than the upper control limit. Line balancing also made use of DES and CLA. The number of items produced per day rose from 1032 to 1289, according to the results. The productivity of labor rose from 46.9% to 4.32%, while that of machines rose from 58.59% to 71.61%. Additionally, the profit earned increased from 22704 to 28358birr (Yemane, 2021). In their 2019 study, Alzoubi et al. examined the tasks involved in sewing T-shirts at the clothing unit. In this study, layout planning and line balancing approaches were employed to increase workers' productivity by reducing idle time while improving the way they now conduct their jobs (Alzoubi et al., 2019).

3. Research Aim and Objectives

The present research is conducted at the pillow sheet set stitiching line at the case textile company. The basic aim of the case study was to improve the productivity of the pillow sheet stitiching line at the case textile company and the mentioned aim was accomplished by following the below-given objectives.

- To optimize the standard allowable minutes (SAMs)
- To optimize the number of machines required for various operations
- To optimize the capacity of the pillow sheet set sewing line

4. Research Methodology

As discussed earlier, the pillow sewing line was selected for the present research. The procedure for studying and improving the line operations at ABC textile company is given in Figure 2.

4.1. Data Collection

Data collection was based on the time study and collection of targets, the number of machines being used, and the capacity of the selected sewing line at ABC textile company. Firstly, the existing SAMs of various operations

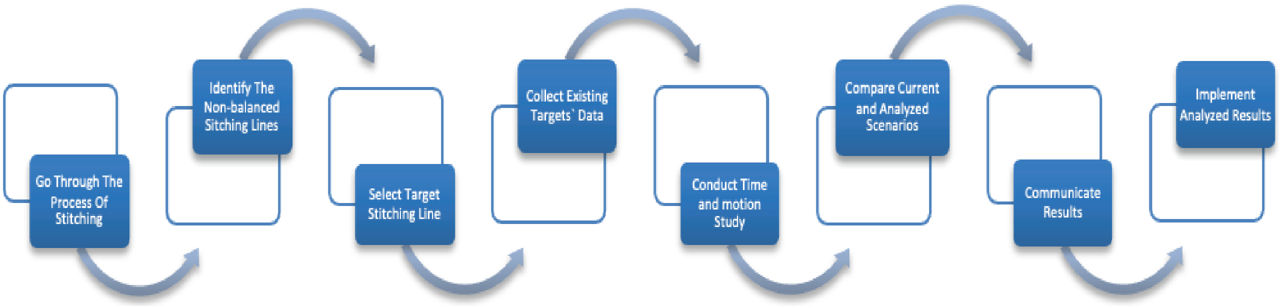

Figure 2: Process followed during the present research.

were collected from the industrial engineering department of the company, and then the operations were restudied so the SAMs could be optimized.

4.2. Data Analysis

When the required data was collected it was got into Microsoft Excel and was organized into tables and graphs were plotted. The graphs used in the analysis were line graphs. Moreover, the comparison of existing and improved sewing line operations was also conducted at last to highlight the significant improvement in SAMs, capacity, and required machines for various sewing operations.

4.3. Equations

The capacity, SAMs, and the number of required machines for each operation were calculated by the below-given equations.

4.3.1. Indices

i refers to the operation *(i=1, 2, 3,…,I)*

n refers to the observation *(n=1, 2, 3,…,N)*

4.3.2. Parameters

O = Observation

r = Performance Rating

o = Operation

a = Allowance

S = SAM

M = Number of required machines

C = Capacity of operation

T = Working time

D = Daily production target

$$S = \frac{\sum_{i=1}^{I}\sum_{n=1}^{N} O_n}{N}(r+a) \tag{1}$$

$$M = \frac{D_i}{T/S_i} \tag{2}$$

$$C = \frac{T}{S_i} M_i \tag{3}$$

5. Results

5.1. Existing Scenario

The given Figure 3 shows the pillow sheet set stitching line; firstly the operator brings the pillow set front to their stitching desk and operates although the operations may change according to the customer requirement and size of the article. In this article, the number of operations was three and in each sheet set, two pillows were placed with one flat and fitted sheet. In this article, the operator is supposed to stitch 3 sides hem with 1cm and label attached and the side hem with 10 cm.

Figure 3: View of the pillow sheet set stitching line.

After the production of the target article, it was forwarded for checking and the checkers checked the Article based on such defects (color shading, thread edging, and hole in an article). If found any defects are discussed above then the article is placed on NCP Box and those defective articles are then forwarded to their respective operators of the nature of the defects and then made as per customer requirement and verified by quality checkers. The defect found was then dropped into the NCP box (see Figure 4) as shown below.

Figure 4: Non-Conforming product (NCP) area.

In the current scenario, SAMs of various operations, the number of machines required for an operation to achieve the set target, and the total capacity of the various operations were collected and are presented in the below-given headings.

5.1.1. Existing Number of Machines Being Used

The SAM that has been calculated can vary every time that depends upon the working efficiency of the worker but we may control it and make it constant if all the accessories of the product should be provided to the workers on time and the spirit of working of workers should not be lost then the Results of SAM all time of the same operation will be same. Workers are uneducated and they didn't know the loss of product that comes due to delivery delay when the product accessories will not be provided to the workers as per the requirement of the customer so they will make some defective products. At the very first reading, the thing we found the dumping of products was everywhere; as a result, WIP (work in process) was found. This was because of the non-availability of packing stuff or the management didn't order from the warehouse and the stitching and checking line forwarded the product towards the packing line after completing their task so as a result dumping was found in the packing line now the working efficiency of packing line worker will b change as they lose their working spirit, as a result, there would be a change in there working SAM.

Table 1 indicates the machine requirement of sheet set pillow for stitching operations. The machine requirement for various operations i.e. operation A (10 cm hem (2 sides)), Operation B (safety (2 sides) and 1 label attach), and Operation C (tacking (1 side)) was calculated to be 5, 5, and 1 respectively. The type of machine for operation A and operation C was the same SNLS (single needle lock stitch) machine; whereas for operation B type of required machine was SF (safety). The working time for all the operations at 85% efficiency was calculated to be 382.5 minutes in a working shift of 8 hours. Furthermore, the target for all the operations was 7000, SAMs that were already calculated for each operation i.e. operation A (0.25), operation B (0.26), and operation C (0.05).

5.1.2. Existing Capacity

Table 2 indicates the capacity of the sheet set pillow for stitching operations. The capacity for operation A, Operation B, and Operation C was calculated to be 7650, 7356, and 7650 respectively.

5.2. After the Improvement

After the existing situation was properly studied deeply in terms of work-study and time study. The slight change was addressed to the targeted sewing section and got them implemented and then the time study of various operations was conducted. The results obtained after the implementation are discussed in the below-given headings.

5.2.1. SAM Calculation

Various activities were supposed to be performed manually to make the material cost comparative analysis report. The description of activities was collected from the costing executive at the planning and costing department of the case company. A stopwatch was used to record

Table 1: Number of machines being used in the existing scenario at the pillow cover sewing section.

Operation Name	*Required Machine*	*Shift Time (min)*	*Working Time (min)*	*Working Time at 85% Efficiency*	*SAM (min)*	*Daily Target (Pieces)*	*Number of Machines Required @ 85%*	*Aggregate Machine Requirement*
A	*SNLS*	*480*	*450*	*382.5*	*0.25*	*7000*	*4.58*	*5*
B	*SF*	*480*	*450*	*382.5*	*0.26*	*7000*	*4.76*	*5*
C	*SNLS*	*480*	*450*	*382.5*	*0.05*	*7000*	*0.92*	*1*

Table 2: The capacity of the existing scenario at the pillow cover sewing section.

Operation Name	*Required Machine*	*Shift Time (min)*	*Working Time (min)*	*Working Time at 85% Efficiency*	*SAM (min)*	*Number of Machines Required @ 85%*	*Capacity*
A	*SNLS*	*480*	*450*	*382.5*	*0.25*	*5*	*7650*
B	*SF*	*480*	*450*	*382.5*	*0.26*	*5*	*7356*
C	*SNLS*	*480*	*450*	*382.5*	*0.05*	*1*	*7650*

the employee`s time that was consumed on each activity during the report preparation. Ten observations of time for each activity were collected and then the average time for each activity was computed in Microsoft Excel as given in Table 1. A look at Table 1 indicates that the manual operation of the material cost comparative analysis report used to take 58.51 minutes to be completed.

Table 3 shows the sheet set pillow stitching operations 10 cm hem (2 sides), safety (2 sides), and 1 label attach and tacking (1 side) these three operations were supposed to be performed to make the ordered piece of product. Ten observations for each operation were taken from the workers with differing task performance efficiency and after the addition of a 17.50% allowance, SAMs were calculated. The SAMs for operations A, B, and C were calculated as 0.22, 0.22, and 0.06 respectively.

5.2.2. Number of Required Machines

The machine requirement after the implementation of the suggested improvements was calculated for various operations. Moreover, for operations A, B, and C the machine requirement was calculated to be 5 SNLS, 5SNLS, and 2 SF machines as given in Table 4.

1.1.1. Capacity Calculation

The capacity after the implementation of the suggested improvements was calculated for various operations. Moreover, for operations A, B, and C it was calculated to be 8693, 8425, and 12750 pieces per shift as given in Table 5.

5.3. Comparison of Existing and Improved Scenarios

The various variables (SAMs, machine requirement, and capacity) associated with the performance of the sewing line before and after the implementation were compared under this heading separately.

5.3.1. Comparison of SAMs

The SAMs of operations A, B, and C were collected before implementation at: 0.25, 0.26, and 0.05 minutes respectively. Whereas, they varied after the implementation; SAMs for operations A, B, and C were calculated to be 0.22, 0.22, and 0.6 minutes respectively as can be seen in Table 6.

Table 6 and Figure 5 indicated that the SAM of various operations decreased/increased by -13.64% (operation A), -14.54% (operation B), and 16.67% (operation C).

5.3.2. Comparison of Number of Machines Being Used

The required number of machines for operations A, B, and C was calculated before implementation as 5 SNLS, 5 SNLS, and 1 SF machines respectively. Whereas, they varied after the implementation; the number of required machines for operations A, B, and C were calculated to be 5 SNLS, 5 SNLS, and 2 SF machines respectively as can be seen in Table 7.

Table 3: SAM Calculations.

Operation	M/C	Observations (seconds) 1	2	3	4	5	6	7	8	9	10	ASCT (min)	Rating	ASCT*Rating	Allowance (17.5%)	SAM (min)
A	SNLS	14	9	12	12	18	14	11	16	13	15	0.22	0.85	0.190	0.175	0.22
B	SF	15	12	15	10	11	13	14	17	12	17	0.22	0.85	0.193	0.175	0.227
C	SNLS	4	4	4	3	3	2	3	3	3	4	0.05	0.85	0.047	0.175	0.06

Table 4: Number of machines being used after making the improvements at the pillow cover sewing section.

Operation Name	Required Machine	Shift Time (min)	Working Time (min)	Working Time at 85% Efficiency	SAM (min)	Daily Target (Pieces)	Number of Machines Required @ 85%	Aggregate Machine Requirement
A	SNLS	480	450	382.5	0.22	7000	4.03	5
B	SF	480	450	382.5	0.22	7000	4.15	5
C	SNLS	480	450	382.5	0.06	7000	1.10	2

Table 5: The capacity of the existing scenario at the pillow cover sewing section.

Operation Name	Required Machine	Shift Time (min)	Working Time (min)	Working Time at 85% Efficiency	SAM (min)	Number of Machines Required @ 85%	Capacity
A	SNLS	480	450	382.5	0.22	5	8,693
B	SF	480	450	382.5	0.227	5	8,425
C	SNLS	480	450	382.5	0.06	2	12,750

Table 6: Current and optimized SAMs.

Operation Name	SAM (min) Before	After	Reduced SAM (%)
10 cm hem (2 Slides)	0.25	0.22	-13.64%
Safety (2 Slides) + 1	0.26	0.22	-14.54%
Tacking (1 Slide)	0.05	0.06	16.67%

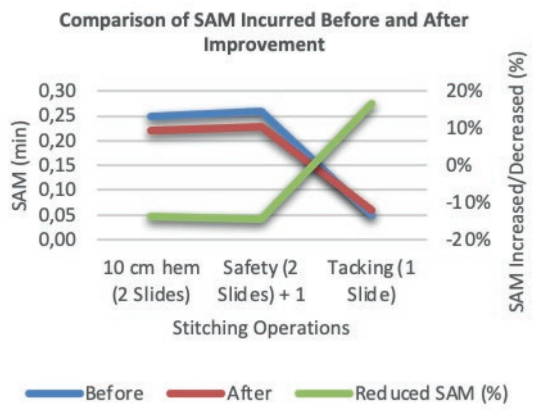

Figure 5: Graphical Representation of existing and improved SAMs of various operations.

Table 7: Current and optimized number of machines.

Operation Name	Number of Machines		Saved Machines (%)
	Before	After	
10 cm hem (2 Slides)	*5*	*5*	*0%*
Safety (2 Slides) + 1	*5*	*5*	*0%*
Tacking (1 Slide)	*1*	*2*	*-100%*

Table 7 and Figure 6 indicated that the number of required machines for various operations decreased/increased by 0% (operation A), 0% (operation B), and 100% (operation C).

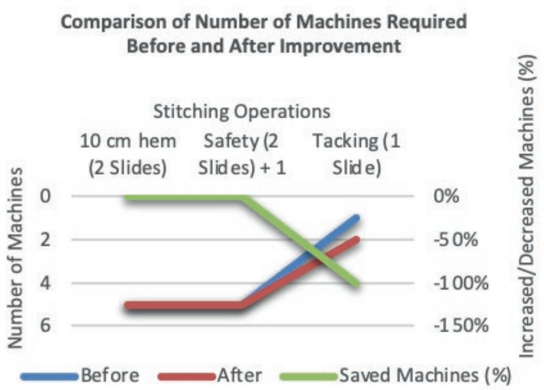

Figure 6: Graphical Representation of an existing and optimized number of required machines at the pillow sewing section of the company.

5.3.3. Comparison of Capacity

The capacity of the sewing line for operations A, B, and C were calculated before implementation as 7650, 7356, and 7650 pieces per shift respectively. Whereas, they varied after the implementation;the capacity of the sewing line for operations A, B, and C were calculated to be 8693, 8425, and 12750 pieces per shift respectively as can be seen in Table 8.

Table 8: Current and optimized capacity.

Operation Name	Capacity		Increased/ Decreased Capacity (%)
	Before	After	
10 cm hem (2 Slides)	*7650*	*8693.00*	*12%*
Safety (2 Slides) + 1	*7356*	*8425.00*	*12.69%*
Tacking (1 Slide)	*7650*	*12750.00*	*40.00%*

Table 8 and Figure 7 indicated that the capacity of the sewing line for various operations decreased/increased by 12% (operation A), 12.69% (operation B), and 40% (operation C).

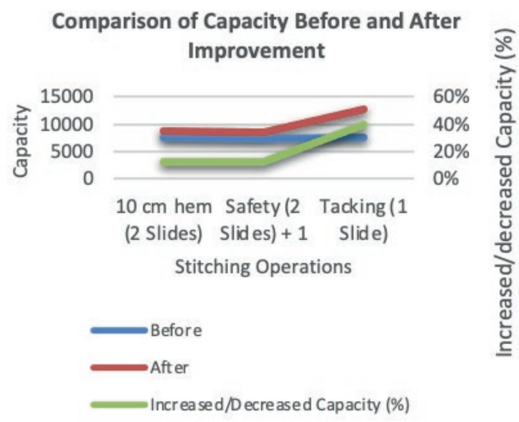

Figure 7: Graphical Representation of existing and improved capacity of the various operations.

6. Discussion

Haque et al., (2018) presented a new sewing layout employing the ALB technique, which resultedin a reduction of 2 workers and an increase in the number of pieces produced each hour from 129 to 235 (22048 pieces per month) (Haque et al., 2018). Utilizing the ideas of lean manufacturing and line balance, Kathem et al., (2021) decreased non-value added operations by 36%, decreased production cycle time by 31%, and boosted productivity by 43% (Kathem et al., 2021). Aung and Tun (2021) enhanced the woman's pencil skirt manufacturing process. The efficiency of the single model assembly line was increased by reducing value-added tasks, and cycle time and creating a balanced workload at each of the workstations through line balancing. Two strategies were employed to increase productivity: suitable sewing operation instruction and supervision, and works-sharing methods across workstations performing similar tasks (Aung & Tun, 2019). Results indicated that SAMs for the operations A and B were minimized by -13.64% and -14.54% respectively; whereas, SAM for the operation C was increased by 16.67%. machine requirement for operation C was increased by 100%; moreover, the capacity for operations A, B, and C was increased by 12%, 12.69%, and 40% respectively. A bigger reduction in cycle time necessitates higher investments in machinery or pricey technology, yet strategies like balancing assist businesses in more effectively allocating resources and boosting production (Alzoubi et al., 2019). Yemani A. (2021) used control limit analysis (CLA) and discrete event simulation on an assembly line to address line balancing (LB) of the BOB T-shirt model (DES). The number of items produced per day rose from 1032 to 1289, according to the results. The productivity of labor rose from 46.9% to 54.32%, while that of machines rose from 58.9% to 71.61%. Additionally, the generated profit increased from 22704 to 28358birr (Yemane, 2021). Alzoubi et al., (2019) increased worker productivity by utilizing line balance and layout planning strategies. Without making significant investments in expensive machinery and cutting-edge technology, it was discovered the product's logistics time significantly dropped (Alzoubi et al., 2019). A helpful step for the real-time adoption of this technology in the industry would be the creation of user-friendly computer software with embedded solutions for line balancing (Chutima, 2020).

7. Conclusion

When it is to the production activities, the little improvements play a significant role in boosting the productivity of the production system. Optimal allocation of human resources, machines, and time are the benefits of line balancing. This research aimed to enhance the productivity of the targeted sewing line at the ABC textile company. In the present research, SAMs, production capacity and number of machines were increased/decreased; SAMs for the operations A and B were minimized by -13.64% and -14.54% respectively; whereas, SAM for the operation C was increased by 16.67%. machine requirement for operation C was increased by 100%; moreover, the capacity for operations A, B, and C was increased by 12%, 12.69%, and 40% respectively. The results indicated that SAMs, capacity, and required machines were optimized by the effective use of time study and motion study. When the workers are provided with the latest technologies (equipment and knowledge), productivity enhances significantly for sure. As per the Pareto principle, 20% of problems are the solution to 80% of problems, in this situation of textile sewing, this concept fits adequately. The reason behind the low production rates was incorrect time study and on the act of correct revision in time study, the production capacity and efficiency went up with hindrance as evident from the discussed results in this research paper

8. Limitations and Future Work

With every passing day, the nature and type of article vary at the sewing line thus it is highly needed for the company to get the model developed for automated line balancing application. Moreover, this work can be extended by the development of a line balancing framework considering the nature of production. The present research was conducted on only one article which was being stitched on the stitching line, there were many articles with varying designs; the time of each operation in each of the articles was variable. This is highly required to balance the line wholly so that it should run smoothly irrespective of the nature and design of the article. This gap can be covered in future research.

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10. Conflict of Interests

There was no conflict of interest among the authors of the present research paper.

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