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Productivity Improvement of Assembly Line in Textile Stitching Unit by Lean Techniques of Line Balancing and Time and Motion Study

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Abstract- Since the resources (machines, time, and money) are the key resources that the base of any business if they are not utilized efficiently then it is not good for the health of the business. The present research focuses on the efficient utilization of time and machine at the stitching line of ABC Textile Company by the use of the line balancing technique. In the present research, the productivity of the flat sheet stitching line was improved at the ABC textile company. A flat Sheet stitching line was selected for the present research, and existing targets of the products were collected from the industrial engineering department of the case company. A stopwatch was used during the time study which was conducted to confirm the collected targets. Moreover, the motion study was also conducted for work simplification. The collected data was put in Microsoft Excel for target calculations and plotting graphs. By applying the line balancing technique at the flat sheet stitching line, the number of stitching machines was reduced from 14 to 10; SAMs of operations was reduced from 1.5 minutes to 1.053 minutes and manpower working time was reduced from 40250 minutes to 19180 minutes. 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.

Keywords- *Stitching, Line Balancing, Productivity, Improvement, Efficiency*

I. INTRODUCTION

The apparel industry is one of the older, largest, and labour-intensive industries across the globe; in developing countries, it is the most dependable industry in the context of export-based industrialization [2]. Companies are highly needed to improve their process on the advent of new technology [3]–[11]. Production strategy needs to be improved in every industry because of fierce competition these days [12]. Over the previous one and a half-century, garment structures have been innovated from manual fitting to their mechanized assembling and robotized sometimes for batch production [13]. Garment sector has been a rigorous sector which emphasizes the use of modern technology [14].

Assembly line is defined as a set of workstations where several tasks are performed to produce a product [15].The Assembly line balancing (ALB) technique is among the methods of operations management for the simplification of problems related to workload and improving line efficiency [13]. Assembly lines are indicated to the specific flow-based production system, the last phase of manufacturing processes is represented by them [16]. Set of workstations are assigned tasks by ALB problem under particular constraints i.e. constraints of cycle time and precedence [16], [17]. Minimization of assembly-line production costs is pursued by optimization processes [17]. ALB and sequencing are among the hardest challenges as having been discussed in the literature [18]. In the apparel industry, current competitiveness is highly associated with the effective and efficient ability to utilize resources by the use of appropriate industrial engineering techniques i.e. time study and line balancing [2]. The goal of line balancing is to minimize the number of workstations and maximize production efficiency [19].

The sewing process is the most important step in the garment manufacturing companies as several workstations are set in order so that ordered processes can be performed. This is the big challenge to make the arrangement or order for performing the tasks [20]. The industrial engineering approach is easier to improve productivity rather than investing a huge capital on buying machinery [21].Tasks of unequal time on the various stations lead to work in process waiting time which is the reason for incurring an extra cost. Working time measurement is higly needed by the companies, particularly small and medium enterprises [22].This is the reason, it has been the consideration of shop floor managers to assign the tasks of equal cycle time to the various workstations for balancing the line [23]. Each workstation is assigned a specific task and each work piece passes the workstation successfully so that the completion of the whole product can be made possible within cycle time. The system of the assembly line was designed to make use of the expertise of every individual on the line to increase efficiency and decrease cycle time [24]. However, line balancing is a topic older than a century but still, it is of researchers' interest because it is directly associated with production efficiency. The improvement and search for a more efficient assembly line balancing approach are required to improve and sustain the efficiency of the line [25]. In the present research, the productivity of the sewing line was improved by the minimization of process cycle time. The cycle time of the various workstations was not the same and sometimes became higher than the total time of the article, when this occurs it might be hard for the line to achieve daily target furthermore the task time of the similar activities is not same this cause increase in a cycle time of the batch.

II. LITERATURE REVIEW

The basic aim of assembly line balancing is either to reduce cycle time or to minimize the number of installed workstations [20]. Germanes et al (2017) defined line balancing as "when everyone is working together in a balanced fashion" [26]. by There are various types of assembly lines i.e. straight-shaped assembly line (StAL), 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).

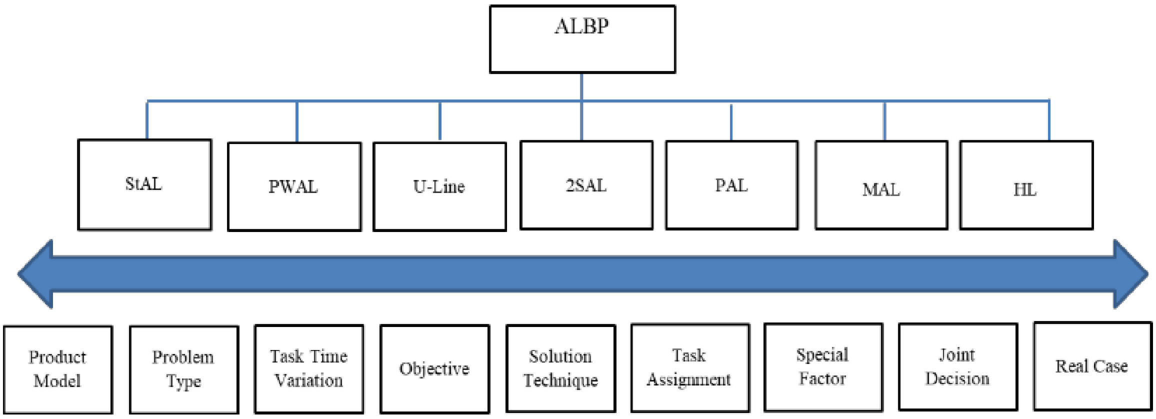

Figure 1. Classification of assembly line balancing problem (Source: [27])

Several researchers have contributed to the literature on the topic of assembly line balancing. Kathem et al. (2021) used lean concepts and a line balancing approach to the minimization of lead time and non-value added activities and to the improvement of productivity in the footwear industry. Rockwell arena software was used in the research. Results indicated that the reduction in non-value added activities were 36%; production cycle time was reduced to 31% and productivity was increased by 43% [12]. Haque et al. (2018) conducted research by using the ALB technique and suggested a new sewing layout; the number of required laborwas reduced from 20 to 18. Moreover, it was indicated that if the labor cost would be 8000tk per month then the total cost can increase from 144000tk to 16000tk per month. This improvement could lead to the increment of 129 – 235 pieces per hour (22048 pieces per month) [13].

Kumar et al. (2020) conducted the case study at the assembly & production line of Automobile Industry to investigate the productivity [28]. 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 [28]. Khan et al. (2020) conducted the systematic review of lean manufacturing practices about the assembly &production lines of Automobile Industry [29]. Rajput et al. (2020) conducted the case study at the production line of Automobile Industry to investigate the productivity [30]. 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 mins to 1.78 mins. 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 [30]. Line balancing, frequent time & motion study, periodic takt time, TPM programs and OEE were also suggested among the other lean manufacturing practices for the improvement in productivity, profitability and quality of the assembly and production lines of Automobile Industry [28]- [30].

Sahito et al. (2020) conducted the case study on the assembly line of pharmaceutical to evaluate the productivity and investigation of lean manufacturing wastes [31]. 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 [31]. Khan et al. (2020) conducted the systematic review of lean manufacturing practices in Pharmaceutical Industry [32]. 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 [31]-[33].

Lakho et al. (2021) conducted the case study on the production line of heavy engineering industry to evaluate the productivity [34]. 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% [34]. Shar et al. (2021) conducted the case study at the production line of large pharmaceutical company to evaluate the productivity [33]. 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 [33]. 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 [33]-[36].

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 [37]-[38]. 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 [1]. There is the great potential for the implementation of lean manufacturing practices for the productivity improvement in the assembly & production lines of Pakistani Industry [39]. 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 [39]. Zaidi et al. (2021) reviewed the benefits & applications of lean manufacturing practices from eight (8) diverse assembly and production lines of various industries [40]. 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 [1], [37]-[40].

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 [41]. The changeover time was reduced from 142 minutes to 117 minutes which in turn increased the overall productivity of flatbed printing machine [41]. Few recent researchers and practitioners have discussed the applications of lean practices to productivity improvement in the production lines of textile industries by [42]-[43]. 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 [44]. 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 [44]. 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 [41]- [44].

Khan et al. (2018) conducted the case study at production line of textile industry of Pakistan where productivity, profitability and quality was investigated [45]-[46]. 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 [45]-[46]. 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 [45]-[46].

Mughal et al. (2021) conducted the case study at the production line of textile stitiching unit where productivity, profitability and quality was investigated [47]. 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 [47]. 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 [46]-[48]. The lean wastes are identified, investigated and suggestion were proposed [46]-[48]. 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 [46]-[48].

Yemani A. (2021) dealt with line balancing (LB) of the BOB T-shirt model by using control limit analysis (CLA), assembly line`s discrete event simulation (DES). The author used CLA for the measurement ofassembly line performance; bottleneck operations were identified at the very first then the LB technique was used for improving the productivity of the model sewing line. BOB T-shirt model was based on 16 operations; thus, the standard minute value of each of the operations was taken out. With the help of CLA and DES, major bottleneck operations were analyzed. Such operations with SMV less than the lower control limit and greater than the upper control limit were named bottlenecks of the sewing section. Moreover, DES and CLA were used for line balancing. Results indicated that production per day increased from 1032 to 1289 pieces. Labor productivity increased from 46.9% to 54.32%; machine productivity improved from 58.59% to 71.61%. The generated profit was also improved from 22704 to 28358birr[49]. The Production process of lady pencil skirts was improved by Aung and Tun (2021). Through the reduction of value-added activities, cycle time, and balanced workload at each of the workstations through line balancing, the efficiency of the single model assembly line was improved. Productivity was improved by two approaches i.e. appropriate training and supervision for sewing operations and work-sharing method were used among those workstations on which similar nature jobs were being performed [23]. Two heuristic approaches were applied by Manaye (2019). He conducted an in-depth review of the literature to find the best possible line balancing technique. Accuracy of standard time was focused on time study and the workload was rearranged among the operators through line balancing techniques for solving apparel sewing problems. To conclude, the cycle time, takt time, and several workstations were considered [19]. Alzoubi et al. (2019) analyzed the tasks required to stitch T-shirt at the apparel unit. Layout planning and line balancing techniques were used in this research to bring about improvement in the current work performance and increment in workers` productivity by decreasing idle time [50].

III. RESEARCH METHODS

A. *Research Aim & Objectives*

The present research aimed to improve the productivity of the flat sheet stitching line at the ABC Company. The mentioned aim was achieved by the following objectives.

- To reduce the unnecessary labor and machines from the assembly line.
- To improve the line efficiency of the stitching line of the sheet set

B. *Research Methodology*

At the very first, ABC textile company was selected for the present research. After going through the whole process of stitching at the case company, non-balanced stitching lines were identified and one of them (see figure 3) was selected for the present research to be conducted.

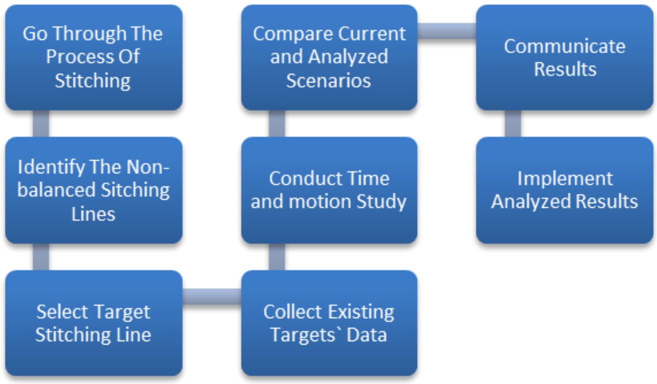

Figure 2. Process followed during the present research

The stitching line was then studied in terms of time study and the results were compared with the existing targets of the stitching line. The results were then communicated to the department and were implemented at the same time as indicated by the flowchart given in figure 2.

Figure 3. View of the flat sheet stitching line

C. *Data Collection*

Data were collected by conducting a time study was the stitching line on one article by using a stopwatch. Ten observations for each operation were collected, and with the help of equations 1, 2, and 3, the daily targets of each operation were calculated. Moreover, the existing daily targets of articles were also collected from the department.

D. Data Analysis

The readings were measured by stop watch and then recorded in Microsoft Excel sheet. for calculation of average operation time, SAM, and daily targets. Moreover, the reduction in the use of resources (working time and machines) and SAMs were also analyzed in detail. The data was presented in the form of tables and graphs.

E. Calculations

Indices, parameters and equations are presented under the below-given headings.

1) Indices

The following indices are used in the data calculations:

i = it refer to the article to be stitched at the stitching line

j = it refers to the operation to be performed on the article *i*

k = it refers to the observation collected for operation *j* during time study

2) Parameters

The following parameters are used in the data calculations:

t = Time of single observation

T = Average observed time from *k* observations

r = performance rating of *j* operation

w = working time per day in minutes

a = allowance given to workers for operation *j*

S = standard allowed minutes for operation *j*

Tr = Daily target calculated for operation *j*

n = Number of available machines at the stitching line.

$$T_{ijk} = \sum_{i=1} \sum_{j=1} \sum_{k=1}^{K} \frac{t_{ijk}}{K} \ \forall \ k = 1, 2, 3, \ldots, K \quad (1)$$

$$S_{ij} = \sum_{i=1} \sum_{j=1} T_{ij} \, r \, (1 + a) \quad (2)$$

$$Tr_{ij} = \sum_{i=1} \sum_{j=1} \left(\frac{w}{S_{ij}} \right) N \ \forall \ n = 1, 2, 3, \ldots, N \quad (3)$$

IV. RESULTS

Under this heading, details of the current target, the suggested target, and their comparison are conducted.

A. Current State of Stitching Line

The current targets of the products were collected from the industrial engineering department of ABC Textile Company. Two operations were required to stitch the flat sheet as can be seen in table 1. The standard allowed minutes for operations A (10 cm Hem (I sides)) and B (10 cm Hem (3 Sides)) were collected to be 0.5 and 1 minutes respectively. In the working time of 450 minutes and at a working efficiency of 85%, the targets of operations A and B were calculated to be 3500 and 3500 by using 5 and 9 single needle lock stitch (SNLS) machines respectively as shown in table 1.

TABLE I. DETAILS OF THE CURRENT STATE OF ASSEMBLY LINE

Operation Name	Required Machine	Working Time (min)	Working Time at 85% Efficiency	SAM (min)	Daily Target (Pieces)	Number of Machines Required
A	SNLS	450	382.5	0.5	3500	4.58 = 5
B	SNLS	450	382.5	1	3500	9.15 = 9

A = 10 cm Hem (1 Sides) and B = 10 cm Hem (3 Sides) + 1 label. It is valid for all the tables

The operations performed on the stitching line were studied and it was revealed that the SAM of operations could be minimized; in this regard, the time study was conducted on the operations (A and B). The time study and the revised SAMs are presented under the below-given heading.

B. Suggested State of Assembly Line

Ten observations for each operation were collected with the help of a stopwatch as indicated in table 2. The average time calculated for operations A and B was 0.408 and 0.618 minutes respectively.

TABLE II. OBSERVATIONS WERE COLLECTED FOR EACH OPERATION BY CONDUCTING A TIME STUDY

Operation Name	Required Machine	Observations										Average Time(min)
		1	2	3	4	5	6	7	8	9	10	
A	SNLS	24	20	32	19	18	34	21	26	24	27	0.408
B	SNLS	39	42	45	25	29	42	44	35	29	41	0.618

At the rating of 85% and 17.5% allowance SAMs for operations A and B were calculated to be 0.419 and 0.634 minutes respectively as indicated in table 3. The targets for operation are presented in table 4; which are the same as are in the existing situation (see table 4).

TABLE III. SAM CALCULATIONS FOR THE FLAT SHEET STITCHING LINE

Flat Sheet Stitching Breakdown						
Operation Name	Required Machine	Average Time (min)	Rating	Average Rating (min)	Allowance 17.5% (min)	SAM (min)
A	SNLS	0.408	85%	0.347	0.06074	0.419
B	SNLS	0.618	85%	0.526	0.091977	0.634

TABLE IV. TARGET CALCULATIONS FOR THE FLAT SHEET STITCHING LINE

Operation Name	Required Machine	Working Time (min)	Working Time at 85% Efficiency	SAM (min)	Daily Target (Pieces)	Number of Machines Required
A	SNLS	450	382.5	0.419	3500	3.73 = 4
B	SNLS	450	382.5	0.634	3500	5.65 = 6

C. Comparison of Current and Suggested States

Comparison of SAMs, number of required machines, and amount of time saved after the improvement are presented in the below-given tables.

TABLE V. COMPARISON OF SAMS BEFORE AND AFTER IMPROVEMENT

Operation Name	SAM (min)		Reduced SAM (%)
	Before	After	
A	0.5	0.419	18.44%
B	1	0.634	38.24%

Table 5 and figure 4 present the comparison of SAMs in which the authors saved 18.44% and 38.24% of SAMs for operations A and B respectively.

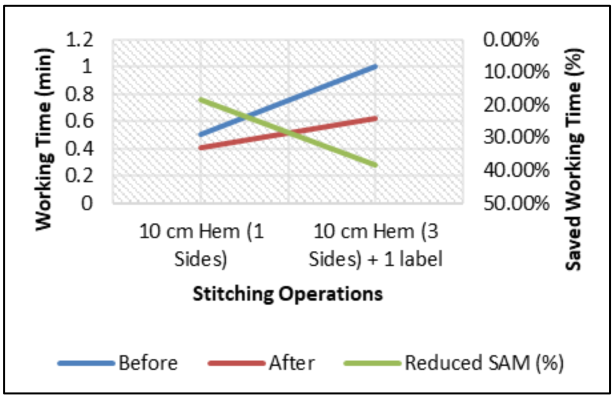

Figure 4. Comparison of SAM of each stitching operation of the stitching line

TABLE VI. COMPARISON OF THE NUMBER OF REQUIRED MACHINES BEFORE AND AFTER IMPROVEMENT

Operation Name	Number of Machines		Saved Machines (%)
	Before	After	
A	5	4	20.00%
B	9	6	33.33%

According to table 6 and figure 5, there was a requirement of 5 SNLS (for operation A) machines and 9 SNLS (for operation B) machines in the existing scenario; after the improvement, the required SNLS machines for operation A and B were calculated to be 4 and 6. The number of machines for operations A and B has reduced by 20% and 33.33% respectively as can be seen in table 6 and figure 5.

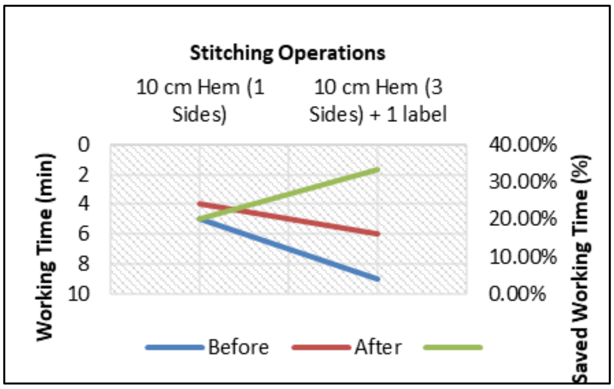

Figure 5. Comparison of required stitching machines for each stitching operation of the stitching line

TABLE VII. COMPARISON OF WORKING TIME BEFORE AND AFTER IMPROVEMENT

Operation Name	Working Time (min)		Saved Working Time (%)
	Before	After	
A	8750	5866	23.96%
B	31500	13314	57.73%

After the applied improvement on the stitching line at ABC textile company, it was revealed that 23.96% and 57.73% of the time of manpower resources performing operations A and B were saved respectively as indicated in table 7 and figure 6.

Figure 6. Comparison of time incurred on each stitching operation of the stitching line

V. Discussion

Kathem et al. (2021) reduced non-value added activities by 36%, production cycle time by 31%, and increased productivity by 43% by using the concepts of lean manufacturing and line balancing [12]. Haque et al. (2018) decreased 2 workers by suggesting a new sewing layout by using the ALB technique; the number of pieces produced per hour was suggested to increase from 129-to 235 (22048 pieces per month) [13]. Yemani A. (2021) dealt with line balancing (LB) of the BOB T-shirt model by using control limit analysis (CLA), assembly line`s discrete event simulation (DES). Results indicated that production per day increased from 1032 to 1289 pieces. Labor productivity increased from 46.9% to 54.32%; machine productivity improved from 58.59% to 71.61%. The generated profit was also improved from 22704 to 28358birr[49]. The Production process of lady pencil skirts was improved by Aung and Tun (2021). Through the reduction of value-added activities, cycle time, and balanced workload at each of the workstations through line balancing, the efficiency of the single model assembly line was improved.

Productivity was improved by two approaches i.e. appropriate training and supervision for sewing operations and work-sharing method were used among those workstations on which similar nature jobs were being performed [23]. The greater reduction in the cycle time needs larger investments in terms of machines or an expensive technology; however, approaches i.e. line balancing help companies to allocate resources efficiently and improve productivity [50]. The development of user-friendly computer software with embedded solutions for line balancing would be a supportive step for the implementation of this technique in the industry for real-time [27]. Alzoubi et al. (2019) improved workers` efficiency by the application of layout planning and line balancing techniques. It was found the logistic time of the product decreased dramatically without huge investments in machines and the latest technology [50].

VI. Conclusion

Line balancing leads to the optimal use of resources (manpower, time, and machines). The study aimed to improve the productivity of the stitching line of the flat sheet which was achieved successfully by reducing the cycle time of each operation, reducing the number of workers for similar operations, and increasing the capacity of production of each operation.The number of machines was 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).

VII. Limitations and Future Work

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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Conflict of Interests

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

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