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Productivity Improvement of Assembly Line-by-Line Balancing Technique: Case Study Textile Manufacturing Company Karachi Pakistan

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study on assembly line balancing theory and concept, focusing on the textile sector in Karachi, Pakistan, specifically the stitching department of a company, aimed to enhance efficiency through meticulous analysis and optimization. By employing time and motion analysis techniques, the research sought to identify and eliminate redundant activities, ensuring a seamless workflow with minimal idle time. The methodology employed involved a comprehensive observation of the entire production process, starting from stitching through to packing. This involved using a stopwatch to meticulously analyze each step of the process, thus gaining insight into the current operational dynamics of the assembly line. Line balancing was ensured by calculating Standard Allowed

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Minutes (SAM), assessing capacity, and determining the required manpower and machine resources. To further refine the efficiency of the stitching line, data collection was conducted using stopwatch techniques, to devise an improved layout. By reducing processing time and minimizing unproductive intervals, the study aimed to establish a foundation for enhanced productivity and streamlined work orders. Various tools were utilized to scrutinize the procedures involved in the production process, encompassing activities, operator proficiency, equipment efficiency, and material usage. This comprehensive approach aimed to optimize the workflow, making it more ergonomic and conducive to efficient operations while ensuring worker satisfaction. The study's analysis specifically targeted the stitching operations related to sheet sets, with a focus on minimizing the number of machines and achieving optimal line capacity. Significant reductions in machine requirements were achieved, with the number of machines for both sheet sets and fitted sheets being reduced substantially. Capacity calculations based on SAM and machine numbers demonstrated the achievement of production targets. Moreover, manpower requirements were reassessed and optimized, resulting in a reduction in the number of workers required for packing operations, thereby further enhancing efficiency.

Keywords: Line balancing; time and motion study; work-study; SAM; assembly line.

1. INTRODUCTION

Henry Ford introduced the manufacturing assembly line in the early 1900s as a highly efficient and productive method for manufacturing a specific product. The basic assembly line consists of linearly arranged workstations connected by material handling devices [1]. The assembly line balancing (ALB) process involves assigning tasks to workstations to ensure all workstations have equal work. Priority relations should not be violated during task assignments, and numerous heuristics have been reported for ALB. This process is commonly used for mass production [2]. The installation of an assembly line is a long-term, capital-intensive decision that requires careful design and balance to ensure efficiency. The system must be re-balanced periodically or after the production process or program changes. Balancing decisions should be carefully chosen considering the strategic goals of the enterprise, as the long-term impact of these decisions is significant [3].

The assembly line is a popular method in manufacturing industries like electronics, textiles, and furniture, but it often leads to bottlenecks due to difficulties in balancing, resulting in wastes like waiting time, work in process (WIP), and overproduction. A lean line balancing could support smooth WIP flow with minimal buffers [4].

Lean manufacturing, also known as Toyota Production System (TPS), is a set of principles, tools, and techniques adopted by industrial organizations to enhance production efficiency and customer value while eliminating waste [5]. Line balancing, a mechanism of cellular manufacturing, involves work-study and lean manufacturing techniques. Time study and stopwatch time study are used to calculate work progression and time spent on specific processes. Lean manufacturing is increasingly adopted in the textile sector to improve product quality and reduce non-value-added activities [6].

Lean manufacturing is the name under which the Toyota production system (TPS) became widely known and later adopted by many companies worldwide. Lean, also denoted as lean Management, Manufacturing (LM), and Lean Principle (LP), is a set of principles, tools, and techniques that many industrial organizations and companies' option to implement, to enhance the efficiency of production and overall customer value while at the same time eliminating waste [7].

Line balancing is a crucial aspect of assembly line efficiency, distributing workload evenly among tasks within a cell or value stream. It is essential for optimizing performance in the garment manufacturing sector, where sewing machines are strategically distributed to meet individual garment style and design requirements. Improving productivity and quality in apparel assembly requires identifying and mitigating factors affecting workers, leading to enhanced production and quality [8].

A time study is a method used to calculate work progress by breaking down operations into smaller, manageable components. It involves selecting average cooperative operators to analyze a specific process by skilled workers to determine the most effective time spent. This technique measures the time needed for a work process to be completed efficiently. Stopwatches are used for this study due to their ease of data recording and ability to record exact data without subtractions. The study helps detect operators and record the time taken for each element over a specific cycle. cycles.

A textile company is a cloth manufacturing company where different processes are carried out and change the raw material (cotton) by applying different processes like spinning, weaving, dying, printing, and stitching to form a finished product. These 3 processes are the complete formation of the finished product (cloth) but some of the small and medium textile companies just do some of the processes like spinning, and weaving, although the textile sector is very complex and focuses on quality improvement and waste reduction therefore the lean manufacturing being adopting widely in textile sector.

The concept of lean manufacturing is now widely used in textile companies, because of the demand for the production and quality of products therefore textile sector now greatly using lean manufacturing tools to eliminate the non-value-added activities from the production process and make the worth of the product different tools used in textile company whereas line balancing greatly used in assembly purpose mostly in stitching line 5s greatly used because to improve the management between the low and middle management and the flow of process remain undisturbed.

1.1 Problem Statement

To improve assembly lines, several steps can be taken. First, analyze the assembly process to identify redundant or unnecessary workers and reorganize positions. Implement a lean manufacturing approach to optimize labor utilization and efficiency. Second, standardize cycle time by implementing standard operating procedures, time studies, training programs, and automation solutions. Third, identify non-value-adding activities and prioritize improvement based on labor costs and efficiency. Implement lean manufacturing principles like 5S to eliminate waste and improve workflow. Continuously monitor and measure key performance indicators to track progress. Fourth, balance assembly lines by analyzing workload and process flow, using techniques like line balancing, cross-training programs, and investing in equipment or technology solutions. Finally, foster a culture of continuous improvement through employee engagement, encouraging active participation in problem-solving and idea-generation initiatives. Implement a structured Kaizen program to identify and address inefficiencies in the assembly process. Regular review meetings and performance feedback mechanisms will help sustain improvements over time.

The study aims to enhance the efficiency of the assembly line. The objectives of the study are to streamline the assembly line process by minimizing excess manpower and machinery, thereby enhancing the efficiency of the sheet set assembly line. Additionally, to suggest or advocate for an optimized layout design following thorough line balancing.

2. LITERATURE

Line balancing assembly involves allocating tasks and activities among operators in a balanced manner to minimize waiting time and ensure equal intensity. This process can increase productivity, reduce costs, and improve product quality in the manufacturing industry by balancing the time it takes to complete different tasks [9]. Assembly line planning involves optimizing process time and productivity through logical and physical operations. Line balancing categorizes work equally for all workstations to minimize resources and maintain productivity. Designing and balancing an assembly line for industrial products is crucial as it eliminates trial-and-error activities and costs associated with large-scale production [10]. Bottlenecks in the sewing assembly line cause longer cycle times and slow processes, reducing production line efficiency. Line balancing is a technique for balancing production lines. Traditional production systems need to be replaced with assembly lines for greater product variability and shorter cycle times [11].

Line balancing operates under two constraints: precedence requirement, represented by a precedence diagram, and cycle time restriction. The precedence diagram shows the sequence of tasks, with work elements represented by nodes. Cycle time is the maximum time a product can spend at each workstation, ensuring that tasks are completed before any other tasks [12].

Lean also denoted as lean Management, Manufacturing (LM), and Lean Principle (LP), is a set of principles, tools, and techniques that many industrial organizations and companies' option to implement, to enhance the efficiency of production and overall customer value while at the same time Eliminating waste[13]. Lean manufacturing practices such as line balancing, frequent time & motion study, periodic time, TPM programs, and OEE have been suggested for improving productivity, profitability, and quality in various industries. A case study on a pharmaceutical assembly line identified defective waste, motion waste, waiting waste, and over-processing waste as the deadliest waste. In the textile stitching unit, line balancing, and time & motion study were applied to improve productivity [14].

Time and motion studies are a systematic and critical approach to analyzing the efficiency and economic efficiency of tasks. They involve breaking down complex jobs into simple steps, observing the sequence of movements to detect wasteful motion, and measuring the time taken for each correct movement. This information is used to calculate production and delivery times, prices, and incentive schemes. Time and motion studies were first proposed by Frederick Winslow Taylor and developed by Frank Gilbreth and Dr. Lillian Gilbreth [15].

The main objectives of time study include determining the standard time for various operations, estimating product costs, predicting work durations, determining the number of machines an operator can run, determining the optimal number of men and machines, providing information for planning and scheduling, balancing work of all workers in a group, and comparing work efficiency of different workers/operators. Techniques for time study include time study using stopwatches, predetermined motion time systems (PMTS), work sampling, and analytical estimating [15].

Waste can be identified in seven forms: defaults, overproduction, waiting, conveyance, processing, inventory, and motion. Each form has its causes and solutions and eliminating them can lead to multiple benefits [16]. Lean manufacturing focuses on reducing waste in the manufacturing process, which includes procedures that customers do not pay for. Waste can be caused by delays, processes, costs, and errors, and can be categorized into seven forms: defects, waiting, overproduction, conveyance, processing, inventory, and motion. Eliminating these wastes can provide multiple benefits, such as increased productivity. Eight Lean manufacturing wastes include over-processing, waiting, unnecessary (motion, transportation, and inventory), over-processing, unused skills, and defects. Implementing these tools can enhance the productivity of the Ethiopian garment industry [17].

Textile companies are responsible for manufacturing cloth by applying various processes like spinning, weaving, dying, printing, and stitching to transform raw materials like cotton into a finished product. While some companies focus on spinning and weaving, the textile sector is complex and focuses on quality improvement and waste reduction. Lean manufacturing is increasingly being adopted in the textile sector to eliminate non-value-added activities and improve product value. Tools like line balancing are used in assembly, particularly in stitching, to improve management between low and middle management and maintain the flow of the process. This approach is crucial for the success of textile companies in the complex and demanding industry.

3. METHODOLOGY

3.1 Line Balancing

Line balancing is the process of leveling workload across all operations in a line to remove bottlenecks and excess capacity. It is essential in mass production where garments are produced in lines or sets of machines, with production per hour varying based on work content, manpower allocation, operator skill level, and machine capacity. Bottleneck operations determine output, and increasing production from these operations is crucial. Line supervisors and work-study officers implement ways to increase production from bottleneck operations to level work across operations. However, some factories use the term "line balancing" instead of "machine balancing" [18,19].

The Simple Assembly Line Balancing Problem (SALBP) is a crucial optimization challenge in production and manufacturing, like the Traveling Salesman Problem (TSP). It focuses on the optimal allocation of tasks in an assembly line environment, aiming to minimize performance metrics like total cycle time, production cost, and resource utilization while respecting constraints. SALBP optimizes the assembly line configuration, maximizing efficiency, minimizing cycle time, balancing workloads, reducing costs, and enhancing flexibility and adaptability. By ensuring each station operates at its maximum capacity, SALBP ensures efficient resource utilization, reduces cycle time, and promotes a smooth workflow [20].

The flow chart Fig. 1 shows the methodology steps that have followed in this study first of all have identified the company, as the interest area was in textile sector so this study conducted in the textile mill limited Karachi Pakistan and observe the whole process of company that how the production take place and how product flow through different processes as this study was focused in the stitching department of company and did time and motion study of whole assembly process from stitching to packing by stopwatch and analyze the current situation of the line that how much time the whole process is taken to complete the product assembly so author takes the before reading and which assure that line is unbalance by calculation of SAM, capacity and man, machine requirement then change some scenarios of whole assemble line like(remove the dumping of the material through which WIP reduced Start Select the company to implement line balancing Make a little research on the company Collect the data using stopwatch; Numbers of worker involves, total time of sheet set completion , sheet set operations time , activities during sheet set change over time. Analyze the current situation of the line Time and Motion study to create a good layout for the line end and reduce the bottleneck again take the final reading of the whole assembly line and find the improvement then accordingly author creates or recommends a better layout for stitching line.

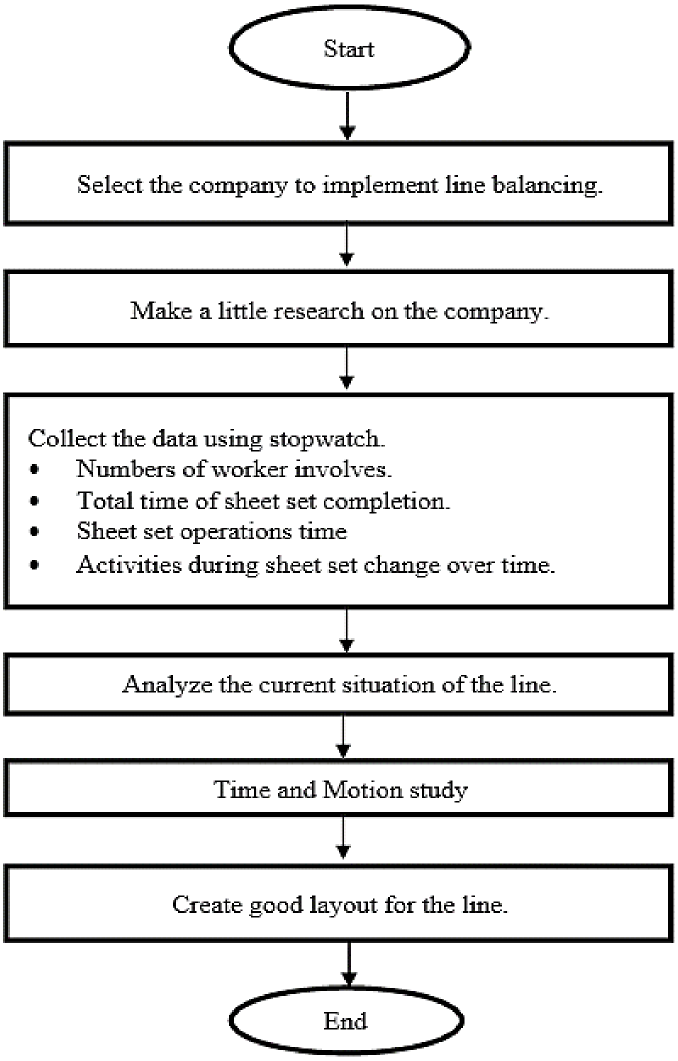

Fig. 1. Flow chart of methodology

Line balancing involves analyzing the current situation of a line and providing the best solution for it. Methods study focuses on decreasing work satisfaction in a job or operation, while the work dimension is concerned with unsuccessful time related to the process and following the formation of time values for the operation. Tools for observing procedures judgmentally are provided, covering activities achieved, complex operators, equipment and tools used, and materials treated or moved.

3.2 Methods of Line Balancing

Analyze the current situation of the line and give the best solution for line balancing.

3.2.1 Analysis of work content using method study

The method study process is primarily concerned with improving efficiency by reducing unnecessary work and time wastage in job operations. It involves critically examining various aspects of the process to identify areas for improvement. The core areas covered in the method study include activities performed, involvement of operators, equipment and tools utilized, and materials managed or transported.

During the study, job data is carefully observed and scrutinized for practicality and necessity. This includes examining factors such as determination, location, arrangement, and method of performing tasks. By evaluating the manufacturing potential and allocation of resources, it becomes evident that many activities within the process contribute little to no value, leading to an increase in processing time. Therefore, the primary objective of the study is to decrease processing time by minimizing non-value-added activities.

To achieve this objective, alternative methods are devised to establish a foundation for new work orders. The perspective of operators is crucial, as their input helps in identifying challenges and allowances in real-world scenarios. Through documentation and engagement with operators, they become significant stakeholders in the process, making it more worker-friendly and suitable. Additionally, workers are provided with training and exercises on the new work orders under the guidance of an industrial engineer, ensuring smooth implementation and adoption of the improved methods.

3.3 Time Motion Study

Time study is a method of analyzing work cycles, involving the use of specific control mechanisms to minimize timing errors. Electronic devices are increasingly used for timing, sometimes converting observed times into basic times. The number of cycles needed depends on the work's variability and the required accuracy level. Time study is a sampling technique, which estimates the time required for a job based on observed times. Statistical techniques can be used to estimate the number of observations required under specific conditions, considering a range of variable conditions and workers [21].

A time study is a method used to calculate work progression by breaking down an operation into specific elements, ensuring a balanced representation of the task. Skilled operators are chosen to perform these elements, and their performance is measured using stopwatch time study techniques. The primary objective is to identify the most efficient time utilization methods for a given process. Stopwatch time measurement is preferred due to its simplicity and accuracy in data recording. Operators are observed and the time taken for each element is recorded over multiple cycles to accurately capture the time required to complete each action. Budgets are allocated for necessary but non-productive actions. The study also focuses on controlling work standards to eliminate idle actions and establish new average times for analysis. Continuous monitoring and adjustment of work values are used to optimize productivity and efficiency in the workplace. In summary, the time study methodology involves meticulous observation and measurement of work processes to enhance productivity and reduce time wastage.

Time motion study calculates work in progression by breaking down operations into smaller, less time-consuming elements and selecting an average cooperative operator(s). A Stopwatch time study is used to examine a specific process by skilled workers to find the maximum effective customs in terms of time. This technique is easier and earlier in data recording, allowing element times to be entered directly on the time study sheet without the need for subtractions.

The time study of fitted sheet sets is used for three articles of sheet set. The stopwatch method calculates the cycle time of each operation of each article, calculates the SAM, and calculates the capacity and machine requirement of the line.

The goal of this study is to decrease processing time through falling unsuccessful times and form the basis for new work orders. Operator views are measured based on allowances and difficulties faced in real situations, making the procedure friendlier and suitable for workers.

4. DATA COLLECTION AND ANALYSIS

4.1 Scope of the Study

The study concentrates on understanding the theory and concept of Assembly line balancing. The data collected from the industry was analyzed using a time and motion study of Line Balancing. The study shall be concerned with line balancing effectiveness by eliminating unnecessary Activities from the Assembly line and providing sequential work activities in the Assembly line with minimum idle time. The main target is to explore the companies suitable for this project, learn and collect necessary data from the existing system, and propose the optimum system based on parameters, for example, cycle time, line efficiency, and balance delay. The project is concerned with the Assembly line balancing of the Sheet set a product of Textile Company in Pakistan that consists of one fitted sheet, one flat sheet, and two pillows.

4.2 Analysis

The analysis of this assembly line results in a set of standardized production in stitching, checking, and packaging operations. The next step was to organize these tasks/activities optimally to achieve the required targets. Line balancing is the major decision problem that arises when constructing or re-configuring an assembly line. Line balancing consists of distributing the total workload uniformly among all the workers present along the stitching, checking, and packing. The overall performance of the system was affected by this distribution of work.

A line balancing problem was associated with the design of a process flow line, which, generally consists of several processes that were joined together by some type of material handling system, for example, the transport of finished products to the warehouse, after ten to fifteen minutes a worker brings a packet of packing box and other accessories materials before the start of new batch, etc. For a given product, the entire assembly line processes are broken down into several work elements or tasks. Each task is performed by workers assigned to the line. The product assembly line was completed by sequential completion of all the tasks.

Every product goes through the same sequence of assembly line tasks in the same order. However, the operations for the completion of the article may be changed due to the change of customer.

4.3 Software Used in the Study

The study conducted for line balancing is primarily based on time and motion analysis, utilizing stopwatches to collect data on various activities. Initially, the data collected is analyzed using Microsoft Excel and Visio software. However, in the final report, only Excel is utilized for analysis purposes. Excel is chosen as the primary tool for analysis due to its versatility, ease of use, and wide acceptance in the industry for data manipulation and visualization. It offers a range of functions and tools that are well-suited for processing time and motion data, such as sorting, filtering, pivot tables, and charting capabilities.

By using Excel, the collected data can be organized efficiently, allowing for the identification of bottlenecks, optimization opportunities, and the balancing of tasks across the production line. Additionally, Excel's spreadsheet format enables easy sharing and collaboration among team members involved in the study. Furthermore, Excel provides the flexibility to customize analysis based on specific requirements or criteria of the study. This includes the ability to create custom formulas, macros, and visualizations tailored to the needs of the line-balancing analysis.

4.4 Current Situation of the Company

The study aims to control the fluctuating SAM (Standard Allowed Minutes) by ensuring timely provision of product accessories and maintaining worker efficiency. Workers are often unaware of potential product loss due to delivery delays, leading to defective products. The first reading revealed widespread product dumping, resulting in Work in Progress (WIP) due to the unavailability of packing materials or management's failure to order from the warehouse. The stitching and checking line forwarded the product to the packing line after completing their task, causing dumping. This shift in working efficiency will result in a change in the SAM (Standard Allowed Minutes) of packing line workers, as they lose their working spirit, affecting their overall efficiency. The study suggests that the timely provision of product accessories and maintaining worker efficiency can help maintain a consistent SAM throughout the operation.

5. RESULTS AND DISCUSSION

This study made a standard by the negotiation with the stitching, checking, and packing line supervisor. To start the assembly line, work the packing line supervisor confirms the availability of all the packing accessories first and then orders to stitching line supervisor to start their work result to avoid dumping of product and run the whole assembly line undisturbed, this study also minimizes the machines, manpower of stitching, checking, and packing line respectively. The target was achieved concerning the capacity of a whole assembly line. The data is shown in the Table 1.

Table 1 shows the before data of sheet set stitching operations machine (M/C) requirement of sheet set flat, fitted, and pillow for the sheet set flat machine requirement that calculated for the operation 10 cm hem (1 side) and 1 cm hem (3 sides) plus 1 label attach is 5 and 10 respectively. A total of 15 machines were required in sheet set flat stitching line.

For sheet set fitted machines requirement that we calculate for the operation 4 corners stitch (4 sides) and elastic attach (4 sides) is 6 and 11, respectively. A total of 17 machines were required in sheet set fitted stitching line. For the sheet set pillow the machine requirement that calculates for the operation 10 cm hem (2 sides), safety (2 sides) plus 1 label attach, and tacking (1 side) is 5, 5, and 1 respectively total in stitching line of sheet set pillow was 11 machines.

Table 2 sheet set data of stitching operations shows the result in before and after format. Here the author has minimized the number of machines as the target of the line was reached concerning line capacity in a sheet set flat, the study has reduced the machines from 15 to 10 machines. In the sheet set fitted we have reduced the machine from 17 to 16 and in a sheet set pillow the machine remains the same because the required target was achieved on these 11 machines according to the line capacity.

Table 3 sheet set data of stitching operations shows the result of capacity in before and after format. Here calculated the capacity with the help of SAM and the number of machines and conclude that the given target has been achieved. In the sheet set flat before data shows that the target in 1cm hem (3sides) +1 label attach not achieved and no of the machine was 8, but after the target has achieved in all of two operations of the sheet set flat. Similarly, the sheet set fitted before data shows that in elastic attach (4 sides)) operation the given target wasn't achieved but after data, it was achieved, and the total number of machines was reduced from 18 to 16. In the last sheet set pillow before data shows that in the starting of two operations the given target wasn't achieved but after data, all three operations achieved the given target.

The Table 4 shows the data set of checking before the line balancing and Table 5 sets the data of checking operations to show the result. Here minimizes the amount of manpower as the target of the line was achieved concerning line capacity in sheet set flat reduced the manpower from 8 to 5. Similarly, the sheet set fitted reduced the manpower from 8 to 5, and in the sheet set pillow, the machine remained the same because the required target was achieved on the 3 pairs of manpower according to the line capacity.

The sheet set data of checking operations shows the result of capacity in before and after format. Here in the sheet set flat both format before and after, the target has been achieved but now this time we gave the preference number of manpower, so the result has shown in the above data sheet, before data the manpower was 8 has achieved the target but in after reading the given target was achieved in 5 manpower. Similarly in the sheet set fitted in both formats target was achieved but reduced the manpower from 8 to 5 and in the sheet set pillow there are several manpower reductions because the target can achieve at least 3 manpower.

The Table 7 shows the Manpower requirement of the sheet set packing operations, before the date the operations were done manually by the workers each worker had a time of 450 minutes in a day and each had a target of 3500 according

Table 1. Machine requirements for sheet set stitching operations before data analysis

Machine (M/C) requirement						
Sheet Set (Flat)						
Stitching Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
10 cm hem (1sides)	SNL	450	3500	0.5	4.58	*5*
1cm hem (3 sides) + 1lbl	SNL	450	3500	1	9.15	10
TOTAL				**1.50**	**13.73**	**15**
Sheet Set (Fitted)						
Stitching Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
4 corners stitch (4 sides)	SNL	450	3SOO	0.6	5.49	6
Elastic Attach (4 sides)	SNL	450	3500	1.2	10.98	11
TOTAL				**1.80**	**16**	**17**
Sheet set (Pillow)						
Stitching Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
10cm hem (2 sides)	SNL	450	7000	0.25	4.58	5
Safety (2 sides) + 1lbl	SF	450	7000	0.26	4.76	5
Tacking (1 side)	SNL	450	7000	0.05	0.92	1
TOTAL				**0.56**	**10.25**	**11.00**

NB: M/C (Machines), SNL (Single needle lock stitch), and SAM (Standard Allowed Minutes)

Table 2. After analyzing data from sheet set stitching operations: Machine requirements

Machine requirement						
Sheet Set (Flat)						
Stitching Operations	**Efficiency**		**8S%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
10 cm hem (1 sides)	SNL	450	3500	0.41	3.73	4
1cm hem (3 sides) + 1lbl	SNL	450	3500	0.62	5.65	6
TOTAL				**1.03**	**9.39**	**10**
Sheet Set (Fitted)						
Stitching Operations	**Efficiency**		**1**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
4 corners stitch (4 sides)	SNL	450	3500	0.44	4.01	5
Elastic Attach (4 sides)	SNL	450	3500	1.14	10.46	11
TOTAL				**1.58**	**14**	**16**
Sheet Set (Pillow)						
Stitching Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
10 cm hem (2 sides)	SNL	450	7000	0.22	4.08	5
Safety (2 sides) + 1lbl	SF	450	7000	0.23	4.14	5
Tacking (1 side)	SNL	450	7000	0.05	0.92	1
TOTAL				**0.50**	**9.13**	**11.00**

NB: M/C (Machines), SNL (Single needle lock stitch), and SAM (Standard Allowed Minutes)

Table 3. Data of sheet set stitching operations capacity

Before						After					
Capacity						**Capacity**					
Sheet Set (Flat)						**Sheet Set (Flat)**					
Stitching Operations	**Efficiency**		**85%**		**capacity**	**Stitching Operations**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
10 cm hem (1sides)	SNL	450	8	0.5	6120 3060	l0cm hem (sides)	SNL	450	4	0.41	3750
1cm hem (3 sides) +1lbl	SNL	450	8	1		1cm hem (3sides) + 1lbl	SNL	450	6	0.62	3714
TOTAL		**450**	**16**	**1.50**	**4080**	**TOTAL**		**450**	**10**	**1.03**	**3728**
Sheet Set (Fitted)						**Sheet Set (Fitted)**					
Stitching Operations	**Efficiency**		**85%**		**capacity**	**Stitching Operations**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
4 corners stitch (4sides)	SNL	450	9	0.6	5738	4 corners stitch (4 sides)	SNL	450	5	0.44	4347
Elastic Attach (4sides)	SNL	450	9	1.2	2869	Elastic Attach (4 sides)	SNL	450	II	1.14	3691
TOTAL		**450**	**18**	**1.80**	**3825**	**TOTAL**		**450**	**16**	**1.58**	**3873**
Sheet set (Pillow)						**Sheet set (Pillow)**					
Stitching Operations	**Efficiency**		**85%**		**capacity**	**Stitching Operations**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
10 cm hem (2 sides)	SNL	450	2	0.25	3060	10cm hem (2 sides)	SNL	450	5	0.22	8693
Safety (2 sides)	SF	450	4	0.26	5885	Safety (2 sides)	SF	450	5	0.23	8315
Tacking (1side)	SNL	450	2	0.05	15300	Tacking (1 side)	SNL	450	1	0.05	7650
TOTAL		**450**	**8**	**0.56**	**5464**	**TOTAL**		**450**	**11**	**0.5**	**8415**

NB: M/C (Machines), SNL (Single needle lock stitch), and SAM (Standard Allowed Minutes)

Table 4. Manpower requirement for sheet set checking operations before data analysis

Manpower requirement						
Sheet Set (Flat)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
Cropping+ Stacking	Manual	450	3500	0.8	7.32	8
Bundle Making	Manual	450	3500	0	0.00	0
TOTAL				**0.80**	**7.32**	**8.00**
Sheet Set (Fitted)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
Cropping +Stacking	Manual	450	3500	0.8	7.32	8
Bundle Making	Manua l	450	3500	0	0.00	0
TOTAL				**0.80**	**7**	**8.00**
Sheet Set (Pillow)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
Cropping+ Stacking	Manual	450	7000	0.1	1.83	2
Turning	Manua l	450	7000	0.03	0.55	1
TOTAL				**0.13**	**2**	**3**

Table 5. After data of sheet set checking operations manpower requirement

Manpower requirement						
Sheet Set (Flat)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
Cropping + Stacking	Manual	450	3500	0.48	4.39	5
Bundle Making	Manual	450	3500	0	0.00	0
TOTAL				**0.48**	**4.39**	**5.00**
Sheet Set (Fitted)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
Cropping+ Stacking	Manual	450	3500	0.47	4.27	5
Bundle Making	Manual	450	3500	0	0.00	0
TOTAL				**0.47**	**4**	**5.00**
Sheet Set (Pillow)						
Checking Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	Working Minutes	Daily Target	SAM		
Cropping + Stacking	Manual	450	7000	0.10	1.83	2
Turning	Manual	450	7000	0.03	0.51	1
TOTAL				**0.13**	**2**	**3**

Table 6. Data of sheet set stitching operations capacity

Before						**After**					
Capacity						**Capacity**					
Sheet Set (Flat)						**Sheet Set (Flat)**					
Checking Operation	**Efficiency**		**85%**		**capacity**	**Checking operation**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
Cropping + stacking	Manual	450	8	0.8	3825	Cropping + stacking	Manual	450	5	0.48	3984.375
Bundle Making	Manual	450	0	0	0	Bundle Making	Manual	450	0	0	0
TOTAL		**450**	**8**	**0.8**	**3825**	**TOTAL**		**450**	**5**	**0.48**	**3984.375**
		Sheet Set (Fitted)							**Sheet Set (Fitted)**		
Checking Operation	**Efficiency**		**85%**		**capacity**	**Checking Operation**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
Cropping + stacking	Manual	450	8	0.8	3825	Cropping+ Stacking	Manual	450	5	0.47	4069.1489
Bundle Making	Manual	450	0	0	0	Bundle Making	Manual	450	0	0	0
TOTAL		**450**	**8**	**0.8**	**3825**	**TOTAL**		**450**	**5**	**0.47**	**4069**
		Sheet Set (Pillow)							**Sheet Set (Pillow)**		
Checking Operation	**Efficiency**		**85%**		**capacity**	**Checking Operation**	**Efficiency**				**capacity**
	M/C Type	**Working Minutes**	**No of m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of M/c**	**SAM**	
Cropping + stacking	Manual	450	2	0.1	7650	Cropping+ Stacking	Manual	450	2	0.10	7650.0000
Turning	Manual	450	1	0.03	12750	Turning	Manual	450	1	0.03	12750
TOTAL		**450**	**3**	**0.13**	**8826.923**	**TOTAL**		**450**	**3**	**0.13**	**8826.923**

Table 7. Before data of sheet set packing operations manpower requirement

Manpower requirement						
Sheet Set						
Packing Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
2 inlay card insertions in polybag	Manual	450	3500	0.2	1.83	2
Fitted Folding	Manual	450	3500	0.13	1.19	2
Flat Folding with stiffener	Manual	450	3500	0.25	2.29	3
Pillow Pairing	Manual	450	3500	0.29	2.65	3
Fitted + Pillow Pairing	Manual	450	3500	0.16	1.46	2
Set Pairing (Fitted. Flat· Pillow)	Manual	450	3500	0.13	1.19	2
Set insertion in a polybag	Manual	450	3500	0.12	1.10	2
Zip closing	Manual	450	3500	0.37	3.39	4
2 Stickers attach	Manual	450	3500	0.44	4.03	5
Insertion in carton	Manual	450	3500	0.12	1.10	2
carton sealing	Manual	450	3500	0.2	1.83	2
TOTAL				**2.41**	**22.05**	**29.00**

Table 8. After data of sheet set packing operations manpower requirement

MANPOWER requirement						
Sheet Set						
Packing Operations	**Efficiency**		**85%**		**M/C Requirement @ 85%**	**M/C Requirement @ 85%**
	M/C Type	**Working Minutes**	**Daily Target**	**SAM**		
2 inlay card insertions in polybag	Manual	450	3500	0.2	1.83	2
Fitted Folding	Manual	450	3500	0.12	1.10	2
Flat Folding with stiffener	Manual	450	3500	0.19	1.74	2
Pillow Pairing	Manual	450	3500	0.22	2.01	3
Fitted + Pillow Pairing	Manual	450	3500	0.14	1.28	2
Set Pairing (Fitted-Flat-Pillow)	Manual	450	3500	0.13	1.19	2
Set insertion in a polybag	Manual	450	3500	0.12	1.10	2
Zip closing	Manual	450	3500	0.33	3.02	4
2 Stickers attach	Manual	450	3500	0.36	3.29	4
Insertion in Carton	Manual	450	3500	0.12	1.10	2
Carton sealing	Manual	450	3500	0.2	1.83	2
TOTAL				**2.13**	**19.49**	**27.00**

Table 9. Data of sheet set packing operations capacity

Before						**After**					
Capacity						**Capacity**					
Sheet Set						**Sheet Set**					
Packing Operations	**Efficiency**		**85%**		**capacity**	**Packing Operations**	**Efficiency**		**85%**		**capacity**
	M/C Type	**Working Minutes**	**No of m/c**	**SAM**			**M/C Type**	**Working Minutes**	**No of m/c**	**SAM**	
2 inlay card insertion in polybag	Manual	450	2	0.2	3825	2 inlay card insertions in polybag	Manual	450	2	0.2	3825
Fitted folding	Manual	450	2	0.13	5884. 6154	Fitted Folding	Manual	450	2	0.12	6375
Flat Folding with stiffener	Manual	450	3	0.25	4590	Flat Folding with stiffener	Manual	450	2	0.19	4026. 3158
Pillow Pairing	Manual	450	3	0.29	3956. 8966	Pillow Pairing	Manual	450	3	0.22	5215. 9091
Fitted + Pillow Pairing	Manual	450	2	0.16	4781.25	Fitted + Pillow Pairing	Manual	450	2	0.14	5464. 2857
Set Pairing (fitted-Flat· Pillow)	Manual	450	2	0.13	5884. 6154	Set Pairing (Fitted-Flat· Pillow)	Manual	450	2	0.13	5884. 6154
Set insertion in polybag	Manual	450	2	0.12	6375	Set insertion in poly bag	Manual	450	2	0.12	6375
Zip closing	Manual	450	4	0.37	4135. 135	Zip dosing	Manual	450	4	0.33	4636. 3636
2Stickers attach	Manual	450	5	0.44	4346. 5909	2Stickers attach	Manual	450	4	0.36	4250
Insertion in Carton	Manual	450	2	0.12	6375	Insertion in Carton	Manual	450	2	0.12	6375
Carton sealing	Manua l	450	2	0.2	3825	Carton sealing	Manual	450	2	0.2	3825
TOTAL		**450**	**29**	**2.41**	**2.6971**	**TOTAL**		**450**	**27**	**2.13**	**4848. 5915**

to their calculated SAM the Manpower requirement of operation 2 inlay card insertion in polybag, Fitted Folding, Flat Folding with stiffener, Pillow Pairing, Fitted + Pillow Pairing, Set Pairing (Fitted flat Pillow), Set insertion in polybag, Zip closing 2 Stickers attach, Insertion in carton, carton sealing is 2, 2, 3, 3, 2, 2, 2, 4, 5, 2, and 2 respectively.

Table 8 shows the set data of Packing operations shows the result. Here the study minimized the amount of manpower from 29 to 27 as the target of the line was achieved concerning line capacity.

Operations show the result of capacity in before and after format. Here is the combined result of Flat, Fitted, and pillow. After performing all the operations of stitching and checking to Flat, Fitted, and pillow they combine into a sheet set and assemble in a packing room the above sheet shows the whole sheet set capacity.

6. CONCLUSION

The study aimed to improve the productivity of an assembly line for manufacturing sheet sets, focusing on the stitching process to the final packing stage. Key objectives included reducing cycle times, optimizing workforce allocation, and augmenting production capacity. A comprehensive approach was employed, utilizing time and motion analysis techniques and Microsoft Excel to analyze data.

Results showed a strategic reduction in machine requirements for Flat and Fitted Stitching Operations and an increase in machinery allocation for Pillow Operations. This realignment of resources led to a more balanced production capacity across various stages of sheet set assembly. Additionally, the study led to a refinement in manpower allocation, resulting in reduced workforce requirements for Flat and Fitted Sheet Checking and Pillow Checking processes. The packing stage also saw improvements, with a reduction in required manpower from 29 to 27 individuals while increasing packing capacity. This optimization of packing resources contributed to overall efficiency gains in the assembly line.

A key aspect of the study's success was the design and implementation of a balanced line layout, which ensured a smooth and efficient flow from stitching to packaging stages. This process involves analyzing several factors such as workflow, production rates, worker skills, and machinery capabilities to ensure smooth operations.

Line balancing is a common method used in this type of study, where tasks along the production line are analyzed and adjusted to ensure optimal operation at each station. Implementing these optimizations can lead to cost savings, improved productivity, and enhanced market competitiveness. It also allows for better resource utilization, contributing to sustainability efforts by reducing waste and energy consumption.

7. RECOMMENDATIONS

The discussion revolves around the importance of timely accessory availability in balancing production lines. The Time Study emphasizes the need for an Integrated Management System (ERP) to streamline operations and reduce Work in Progress (WIP). The company should also provide comprehensive training to supervisors and floor in-charges on the ERP system to minimize unnecessary movement, reduce waiting times, and enhance lead times in the production process. This strategic move aims to reduce unnecessary movement and improve overall efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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