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Productivity Improvement through Line Balancing - A Case Study in an Apparel Industry

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KeyWords

Line balancing, Line efficiency, Labor productivity, Work sharing method, Productivity

ABSTRACT

Line Balancing is equalizing the workload across all operations in a line to remove bottlenecks and excess capacity. Line balancing helps to assign tasks to workstations, so that optimal assignment is achieved. This study deals with increasing overall efficiency of single model assembly line by eliminating bottlenecks and reducing the non-value-added activities at each work station by line balancing and work sharing method. The research methodology here includes calculation of hourly production capacity, cycle time per head of each process, identifying the bottlenecks and non –value-added activities and balancing of the production line by work sharing method. Line balancing by work sharing methods results in improved line efficiency and improved labor efficiency at the same time.

Introduction

Apparel industry is one of the world's vital industries and the garment industry is a fundamental one within the supply chain of apparel industry. Within a single decade garments industry in Bangladesh has emerged as the single dominant industry [1]. It makes a significant contribution to the national economy by creating generous employment opportunities and reducing poverty through socioeconomic development [2]. The sector became very important concerning employment, foreign exchange earnings and its contribution to GDP. Still, in terms of productivity, its performance is below the mark even in the tough competitive market. To survive in this competitive market, productivity improvement is a vital issue in the case of RMG industry. In this business environment, the design of such manufacturing systems, which involves the design of products, processes and the plant layout before physical construction, becomes more and more important. Particularly, the design of an efficient assembly line has a considerable industrial importance [3]. Reducing Lean wastes and decreasing process bottlenecks will certainly improve the efficiency and productivity. The Finishing line is one of the critical phases in the RMG production. The production process of garments industry can be grouped into three main stages cutting, sewing and finishing [4]. The finishing line consists of a set of workstations in which several tasks are performed to enhance the suitability of the fabric for end use and the dimensional stability of the products. Tasks are assigned to operators based on their labor skill levels. Required manpower for each operation is determined through the calculation of cycle time and benchmark target per hour. Unequal workload among workstations results in bottlenecks and WIP. Work sharing method plays a vital role in eliminating these bottlenecks. Finally, a balanced layout is modeled for the finishing line.

Literature review

The assembly line balancing problem (ALBP) involves distributing the tasks needed to manufacture any unit of the products to be assembled among the work stations along a manufacturing line [5]. Line Balancing is leveling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity [6]. The issue of line balancing with limited resources has always been a serious problem in industry [7]. ALBP has been an active field of research over the past decades due to its relevancy to diversified industries such as garment, footwear and electronics [8]. The assembly line balancing problem has received considerable attention in the literature since 1954 [9]. The assembly line balancing problem was first introduced by Bryton in his graduate thesis. In his study, he accepted the number of workstations as constant, the workstation times as equal for all stations and work tasks as moving among the workstations. The first article was published in 1955 by Salveson. He developed a 0-1 integer programming model to solve the problem. However, since the ALB problem falls into the NP hard class of combinatorial optimization problems (Gutjahr and Nemhauser, 1964), it has consistently developed the efficient algorithms for obtaining optimal solutions. COMSOAL (Computer Method of Sequencing Operations for Assembly Lines) was first used by Arcus in 1966 as a solution approach to the assembly line balancing problem [10]. Numerous research efforts have been directed towards the development of computer-efficient approximation algorithms or heuristics (e.g. Kilbridge and Wester, 1961; Helgeson and Birnie, 1961; Hoffman, 1963; Mansoor, 1964; Arcus, 1966; Baybar, 1986a) and exact methods to solve the ALB problems. (e.g. Jackson, 1956; Bowman, 1960; Van Assche and Herroelen, 1978; Mamoud, 1989; Hackman et al., 1989; Sarin et al., 1999) [11].

Classification of ALB problem is primarily based on objective functions and problem structure. Different versions of ALB problems are introduced due to the variation of objectives [12]. ALBP with various objectives are classified into three types:

- ALBP-I: minimizes the number of workstations, for a given cycle time.
- ALBP-II: minimizes the cycle time, for a given number of workstations.
- ALBP-III: maximizes the workload smoothness, for a given number of workstations [13].

In type I problems, the ALBP of assigning tasks to workstations is formulated with the objective of minimizing the number of workstations used to meet a target cycle time. It can result in low labor costs and reduced space requirements. Type II problems maximize the production rate of an assembly line [14]. Since this objective requires a predetermined number of workstations, it can be seen as the counterpart of the previous one. In general, shop managers are concerned with the workload equity among all workers. The issue of workload smoothing in assembly lines allocates tasks among a given number of workstations, so that the workload is distributed as evenly as possible. This problem is known as Type III problem. The project here was focused on type-1 line balancing problem. Relevant data were collected from an apparel industry. The objective of the project was to eliminate the bottleneck and WIP which result in increased productivity.

Methodology

To balance the finishing line relevant data was collected from the line.

At first, for a certain garment order the number of operations, sequence of operations, seams length, types of fabric, number of workers, working hours, machine efficacy etc. were identified. The time needed for each operation by every worker was calculated. Tasks are then assigned to the operators based on their labor skill level.

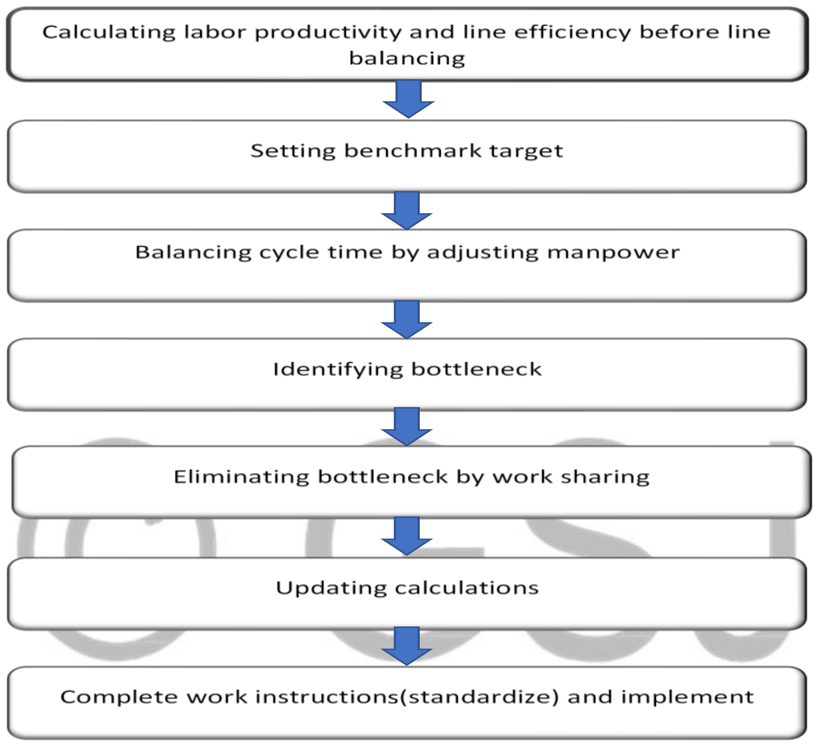

Figure 1: Steps involved in the line balancing

For each operation the average cycle time was calculated by using stop watch. The S.M.V., Takt time, cycle time, labor productivity, line efficiency and target per hour were calculated using following equations:

Capacity per hour = $\frac{60}{\text{SMV}}$

Daily production = $\text{Capacity per hour} \times \text{Working hours}$

Tact time = $\frac{\text{Total SMV}}{\text{Number of operators}}$

Target = $\frac{\text{Total manpower per line} \times \text{Total working minutes per day}}{\text{SMV}}$

Standard minute value (S.M.V) = $(\text{Average cycle time} \times \text{Allowance})$ in minute

Theoretical manpower = $\frac{\text{Benchmark target per hour}}{\text{Process capacity per hour}}$

Labor productivity = $\frac{\text{Total number of output per day per line}}{\text{Number of workers worked}}$

Line efficiency = $\frac{\text{Total output per day per lines} \times \text{SMV}}{\text{Total manpower per line} \times \text{Total working minutes per day}} \times 100\%$

The benchmark target per hour was determined considering the cycle time and desired efficiency of the line. Variation in the cycle time per head results in variation in the hourly capacity of the operations. In order to reduce this variation and adjust the hourly capacity of the operations required manpower were calculated for each operation. The adjusted hourly capacity of different operations was then compared with the benchmark target capacity to identify the bottleneck processes which was the prime concern. Higher cycle time per head or lower hourly capacity than benchmark target indicates the bottleneck process. The bottleneck operations and balancing operations (operations which have higher hourly capacity than benchmark target) were then identified. After that, the line was balanced by sharing workload among workers who has experience in both bottleneck process and balancing process. The experienced worker shared their excess time on bottleneck process after completing tasks on balancing process. In this manner the bottleneck processes were balanced. Based on the updated calculation a balanced finishing line production layout was modeled.

Data Collection and Analysis

To balance the line the first step is to specify the sequential relationships among tasks.

The process wise capacity of the finishing line has been shown in Table 1 where Standard minute value (S.M.V) has been calculated by taking average cycle time for each process and considering allowances. Currently the labor productivity is 31% and line efficiency is 67%.

Here the benchmark target for the line calculating total 75 manpower worked on that line for 600 minutes. With a S.M.V value of 13 we have standardized the Benchmark target of 300 pieces of garments at 86% efficiency.

Table 1: Labor productivity, Line efficiency and Target per hour before line balancing

Total output per day	2300
Total manpower	75
Working time	600
S.M.V.	13
Takt time	0.214
Cycle time	0.261
Labor productivity	31
Line efficiency	67
Target per hour	346 (efficiency 100%)
	277 (efficiency 80%)
	208 (efficiency 60%)
Benchmark Target Per Hour	300 (efficiency 86%)

Figure 2 depicts the variations in cycle time of different process from the targeted time. The higher cycle time then the benchmark cycle time will eventually result in operations having production capacity lower than the benchmark target and vice versa. Comparing hourly capacity of each process to the 86% benchmark target, we have identified that some operations hourly capacity is significantly less than benchmark target where the remaining operations hourly capacity is higher than benchmark target. Total production has been blocked in these work stations and large work in process (WIP) has been stuck in these bottleneck processes while the other tasks are responsible for non-productive time. The target is to adjust the cycle time per head of the tasks to the value as close as the benchmark possible.

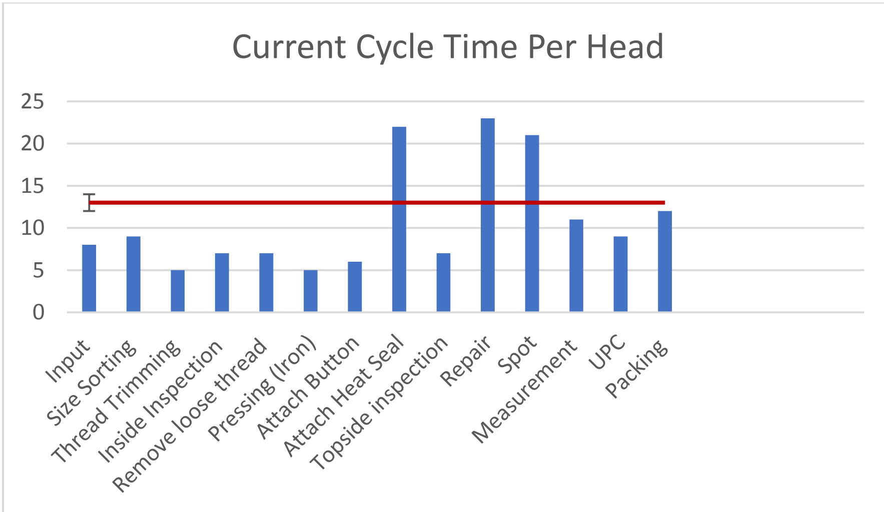

Figure 2: Variations in process cycle time

In this figure 3 the existing layout of the finishing line is shown in the sequential order in which material flows. The blue arrow indicates the work flow.

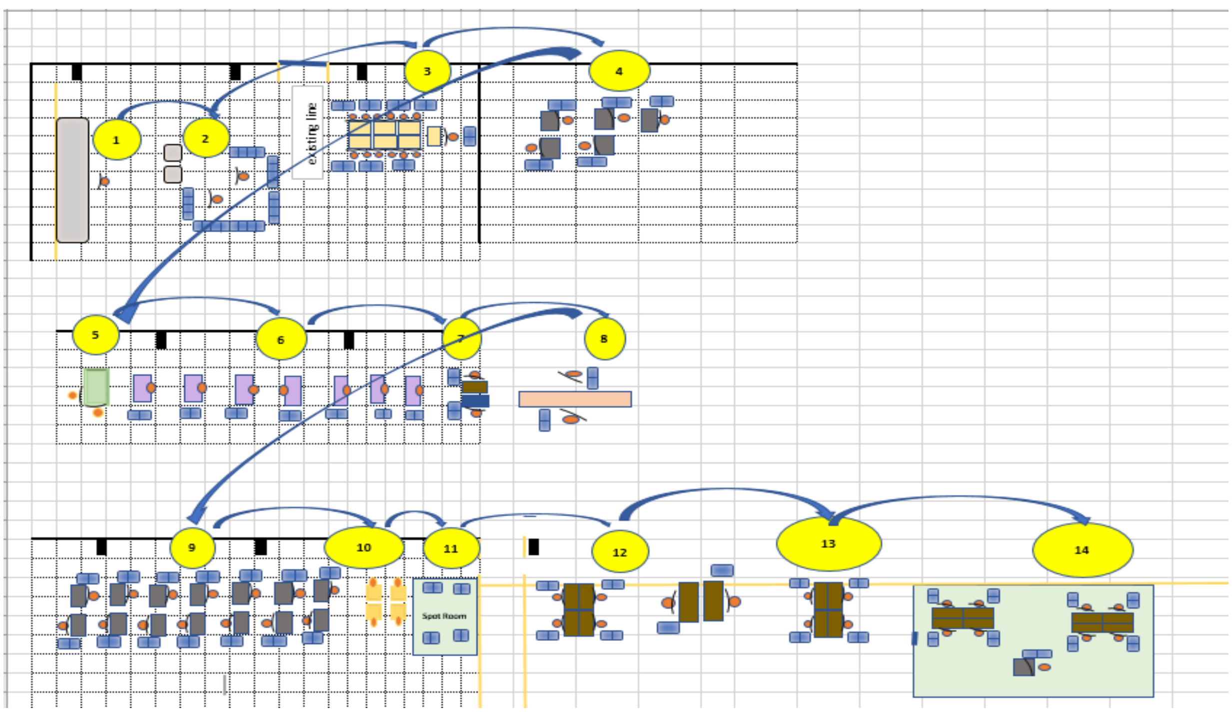

Figure 3: Existing layout of the finishing line

The table 2 shows the current manpower and the proposed manpower based on the adjustment of the cycle time. The hourly capacity shows the impact of adjusting cycle time. Adjusting cycle time per head results in adjusted hourly capacity. The adjustment of manpower with respect to cycle time per head results in requirement of 70 manpower where 75 workers are employed in current layout.

Table 2: Process wise manpower distribution, capacity and cycle time calculation

Serial No.	Operation	Current Manpower	Required Manpower	Estimated Standard Cycle Time(Sec)	Hourly Capacity	Adjusted Hourly Capacity	Cycle Time Per Head	After Cycle Time
1	Input	1	1	8.11	444	444	8	8
2	Size Sorting	2	1	14.34	502	251	7	14
3	Thread Trimming	13	6	63.81	733	339	5	11
4	Inside Inspection	5	4	42.00	429	343	8	11
5	Remove Loose thread	2	1	14.20	507	254	7	14
6	Pressing (Iron)	7	4	44.40	568	324	6	11
7	Attach Button	2	1	13.82	521	260	7	14
8	Heat Seal	2	4	44.20	163	326	22	11
9	Topside inspection	14	10	100.80	500	357	7	10
10	Repair: Sewing	4	9	92.40	156	351	23	10
11	Spot (Repair)	4	8	84.00	171	343	21	11
12	Measurement	6	6	66.00	327	327	11	11
13	Attach UPC	4	4	43.80	329	329	11	11
14	Packing	9	11	110.42	293	359	12	10
Total		75	70					

After balancing cycle time by adjusting the manpower, the cycle time of the operations are now closer to the benchmark value as shown in figure 4.

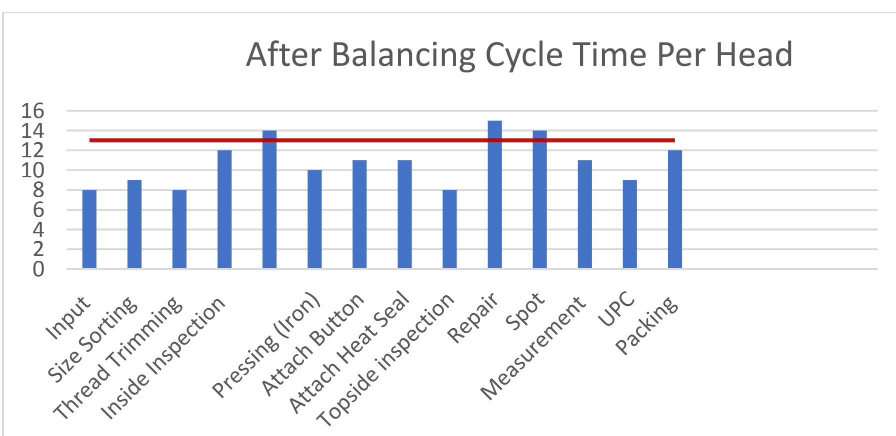

Figure 4: Variation in process cycle time after lie balancing.

The figure 5 shows the finishing line layout after adjusting the manpower. The sequential order of the operations remains same where the assigned manpower reduced from 75 to 70.

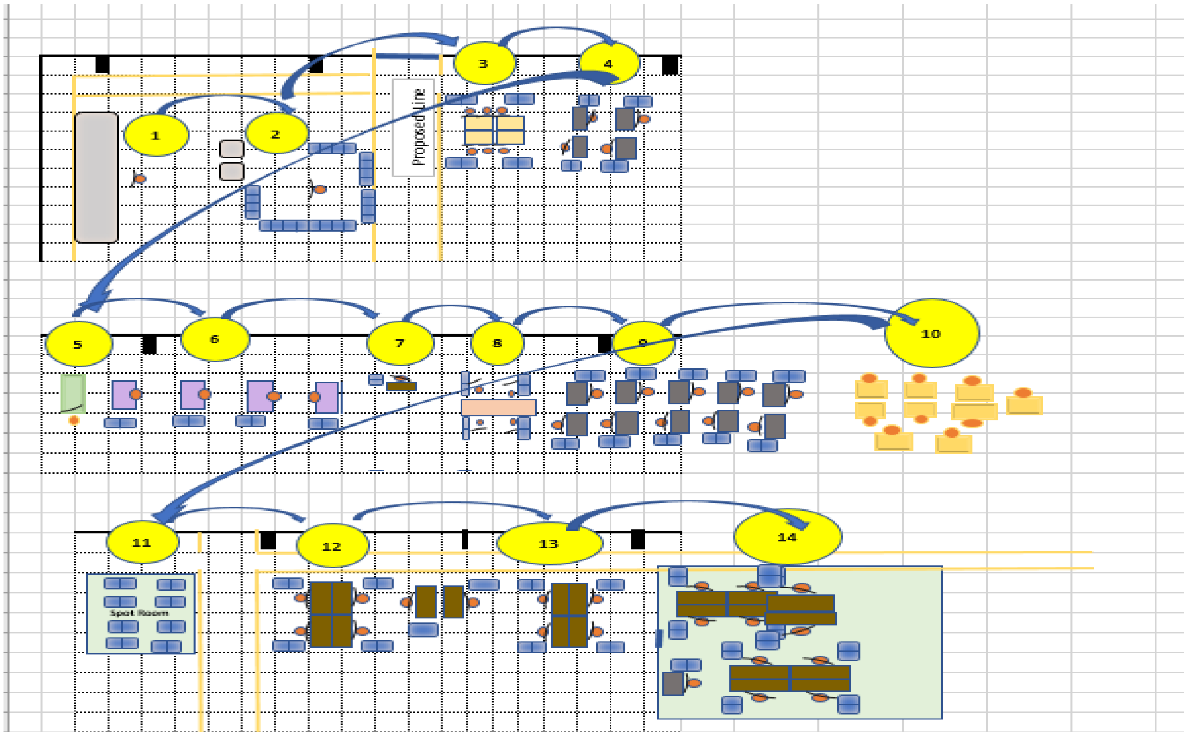

Figure 5: Finishing line layout after line balancing

Balancing method is very essential to make the production flow smoother. Line is balanceable if a perfect balance can be obtained via work-sharing between adjacent stations. Considering working distance, type of machines and efficiency, workers who have extra time to work after completing their works, have been shared their work to complete the bottleneck processes. Previously identified three bottleneck processes have been plotted in the left side of the Table 3. Skilled worker from the process input can share 15 minutes on size shorting which adjust the bottleneck process size shorting. Similarly, the skilled worker from the process Inside inspection and Pressing (Iron) can share 15 minutes on Remove loose thread and Attach button respectively.

Table 3: Work sharing between Bottleneck process and Balancing process

Sl No	Bottleneck Process				Balancing Process			
	Process Name	Process No	Hourly Capacity	Balanced Hourly Capacity	Process Name	Process No	Hourly Capacity	Balanced Hourly Capacity
1	Size Sorting	2	251	313	Input	1	444	333
1 skilled worker from process #1 can work for 45 min and share work with process #2 for last 15 min								
2	Remove Loose Thread	5	254	317	Inside Inspection	4	343	318
1 skilled worker from process #4 can work for 45 min and share work with process #5 for last 15 min								
3	Attach Button	7	260	325	Pressing(Iron)	6	324	302
1 skilled worker from process #6 can work for 45 min and share work with process #7 for last 15 min								

The work sharing of the three tasks will remove the bottlenecks of the finishing line while adjusting the hourly capacity of all tasks.

Table 4: Process wise adjusted hourly capacity after line balancing

Operation	Adjusted Hourly Capacity	Balanced Hourly Capacity
Input	444	333
Size Sorting	251	313
Thread Trimming	339	339
Inside Inspection	343	318
Remove Loose thread	254	317
Pressing (Iron)	324	302
Attach Button	260	325
Heat Seal	326	326
Topside inspection	357	357
Repair: Sewing	351	351
Repair: Spot	343	343
Measurement	327	327
Attach UPC	329	329
Packing	359	359

In figure 6 by plotting process wise capacity in a line graph shows the variation of each process from the bench mark target. The Hourly capacity graph shows that the outputs of all operations are higher than the benchmark hourly capacity.

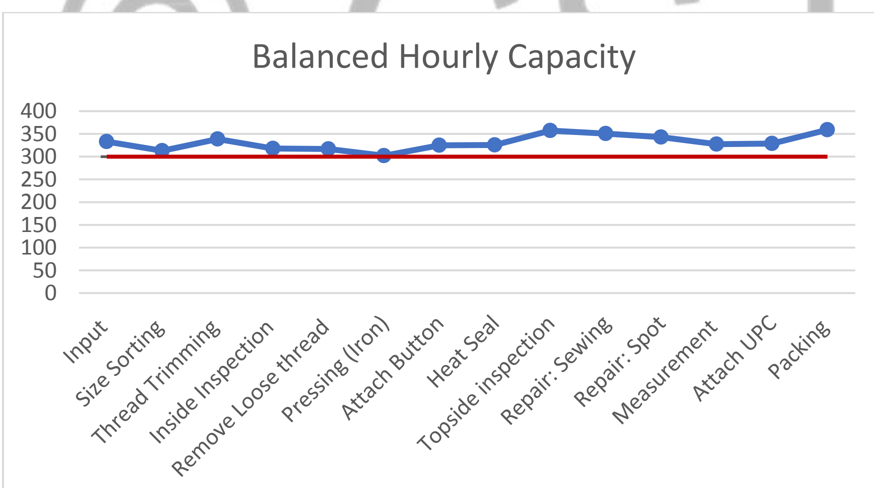

Figure 6: Variation in each process hourly capacity per hour compare to benchmark target

The final proposed layout for the finishing line is shown in the figure 7. The yellow arrow indicates work sharing by the skilled workers in between bottleneck processes and balancing processes.

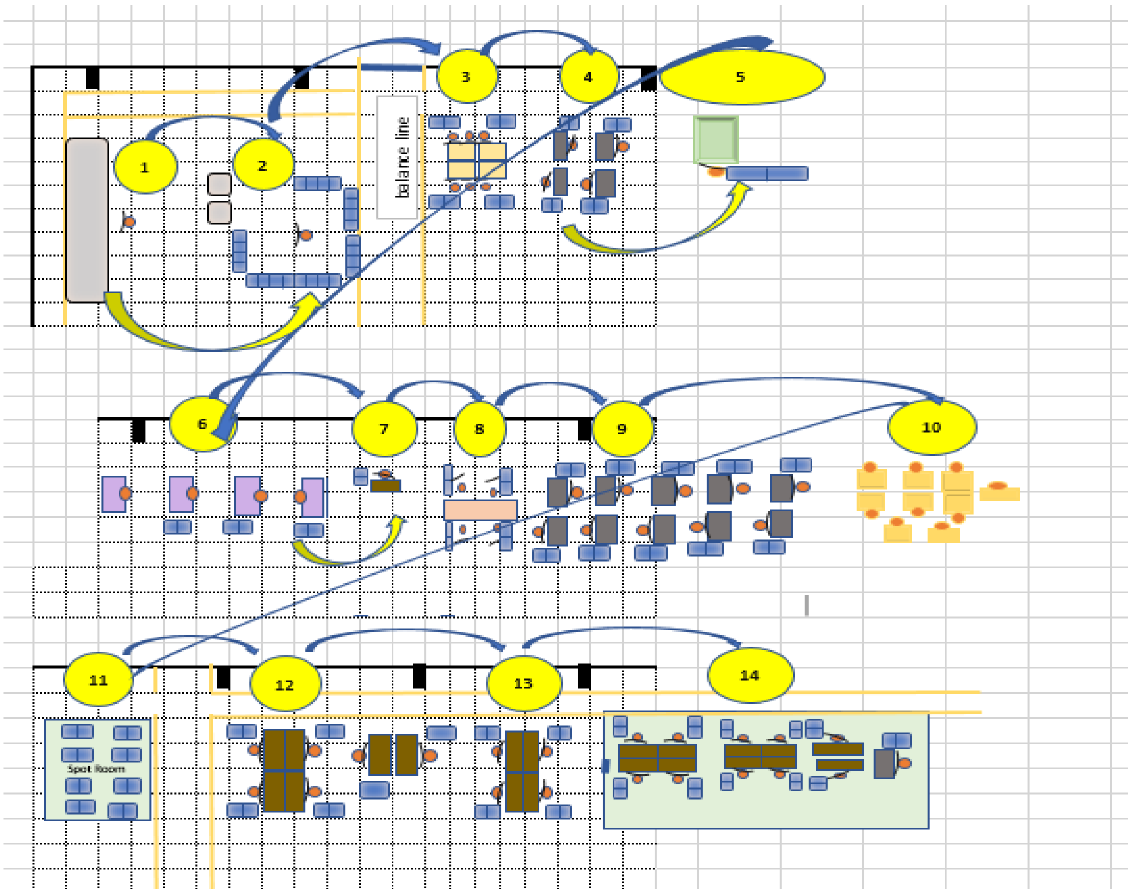

Figure 7: Proposed finishing line layout after line balancing

Result and Discussion

The unbalancing problem in a production line is considered here. Current manpower is 75 which can be reduced to 70 by considering the cycle time per operation. Hence, the labor productivity will increase from 31% to 39.68%. The results provide evidence that the bottleneck processes are Size Sorting, Remove Loose thread, Attach Button. Total production has been blocked in these work stations and large work in process (WIP) has been stuck in these bottleneck processes. On the other hand, the operators of Input, Inside Inspection and Pressing (Iron) operations have non-productive time as the current hourly production capacity for these operations are far greater than the benchmark capacity. For this reason, the workers of the operations Input, Inside Inspection and Pressing (Iron) will work 45 minutes on their workstations and share 15 minutes in workstations Size Sorting, Remove Loose thread, Attach Button respectively. Here, a balanced layout is proposed. Proposed layout model has been followed the logic of modular system (worker works on more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training and supervision is essential to achieve the optimum improvements on productivity and efficiency. In this manner, the hourly capacity of the bottleneck processes Size Sorting, Remove Loose thread, Attach Button will become 313, 317 and 325 respectively. The total production will hence increase to 2778 with manpower 70. The line efficiency will increase from 67% to 86%.

Table 5: Labor productivity, Line efficiency and Target per hour after line balancing

Total output per day	2778
Total manpower	70
Working time	600
S.M.V.	13
Labor productivity	39.68
Line efficiency	86
Target per hour	323 (efficiency 100%)
	291 (efficiency 90%)
	193 (efficiency 60%)

Therefore, by changing the manpower and locations of stations and performing some improvements in activities of one station, the improvement scenarios are generated. Further improvements in the productivity can be achieved by considering large amount of order.

Conclusion

Productivity improvement is an important issue in RMG sector. The profit earning of apparel industry largely depends on productivity improvement. This study shows the way of improving the production efficiency by using work sharing method. Number of operators are reduced by considering process wise cycle time per head. A final layout for the finishing line is proposed. The proposed layout model has been followed the logic of modular system (worker works on more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. This calculation could be justified by considering different line of the production floor. Result would have been more effective if the order considered is larger than the current order. Lean tools are also very important for reducing wastes and improving quality. So, further research could be done by using combination of lean and work study techniques.

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