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Multi-Objective Mixed Model Assembly Line Balancing Using Mixed Integer Linear Programming

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Abstract Now a day's Mixed-Model Assembly Line Balancing is becoming more and more popular for mass production system. In mass production, huge costs, time, equipment and manpower are involved. Therefore, to reduce those cost, time, equipment and manpower, Mixed-Model Assembly Line Balancing can be very useful. In Single Model Assembly Line Balancing, only one type of product or model can be produced. But in Mixed- Model Assembly Line Balancing, multiple objects or multiple products can be produced at the same time.Therefore, mixed model assembly line balancing can provide better results in optimizing these resources. Different type of methods can be used to solve Mixed-Model Assembly Line Balancing problem. However, we have used a framework of Mixed Integer Linear Programming to solve a mixed model assembly line problem for garments industry. The proposed model using the Mixed Integer Linear programming outperforms other traditional model for optimizing the set of resources. Moreover, in this paper cost, space and cycle time have been reduced simultaneously. And, a real life illustration has been shown for better understanding for the practitioner.

Keywords: *assembly line balancing, mixed model assembly line, mixed integer Linear Programming, multi-objective optimization*

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1. Introduction

The productionsystem is classified into mass production system and batch production system. In mass production system, manufacturing facility is geared up to produce the products of interest in large volume, whereas in batch production system, manufacturing facility is geared up to produce the products in much smaller volumes. Now a days, because of competitions and globalization that creates a dynamic, changeable and uncertain global market that needs greater flexibility and responsiveness which creates more complexity in production line. To handle this complexity, methods of Operations Research are often used to support the decision maker to plan flexible and optimal assembly lines. An assembly line is a set of sequential workstations linked by a material handling system. In each workstation, a set of tasks are performed using a predefined assembly process in which the following issues are defined: task time, the time required to perform each task, sequence of the tasks. Line balancing divided into three categories these are: Single Model Assembly Line Balancing, Mixed Model Assembly Line Balancing, and Multi Model Assembly Line Balancing. Due to high cost to build and maintain an assembly line, the manufacturers produce one model with different features or several models on a single assembly line. Under these circumstances, the mixed-model assembly line balancing problem arises to smooth the production and decrease the cost.

The design of the assembly line system to assemble a product mainly involves minimization of the number of workstations, balancing workload between workstations etc. which helps a company to better utilize its facilities and produce exact number of units of a product to meet the demand of that product in the case of custom made product. Many manufacturers are converting their production lines into mixed model assembly line from single model assembly line. In mixed-model production, different products or models are produced on the same line with the models interspersed throughout a production sequence. This helps manufacturers provide their customers with a variety of products in a timelyand cost effective manner. When a component is machinedusing a product layout, the necessary machines are to be arranged as per the process sequence of that component, whose layout design does not warrant a complex analysis. In this paper, the design of the mixed- model assembly line balancing is considered. The inputs for the design of the mixed-model assembly line balancing are as listed below [1]:

- Precedence network of tasks
- Task times
- Cycle time or number of workstations

The precedence network defines the immediate precedence relationships among the tasks of assembling a product. The execution of each task requires certain time, which is known as task time. This may be deterministic or probabilistic. The cycle time is the time between consecutive releases of the assemblies at the end of the line or the total time allocated to each workstation in the assembly line.Formally, a Mixed-Model Assembly Line Balancing problem can be stated as follows: given n models, the set of tasks associated with each model, the performance times of the tasks and the set of precedence relations which specify the permissible orderings of the tasks for each model, the problem is to assign the tasks to an ordered sequence of stations such that precedence relations of each model are satisfied and some performance measures are optimized. In Mixed Model ALBP, different models on one product are produced in one assembly line. In assembly lines there are many work stations which are linked to each other by a material handling system. Based on objective function, there are two types of assembly line balancing problem. They are-

Type 1: In this, the production rate, cycle time, assembly tasks and time for those tasks will be given. The purpose is to minimize the number of work stations and there cycle time will be constant.

Type 2: This is the opposite characteristic of type 1. There the number of work stations and cycle time or production time will be given and the purpose is to minimize the cycle time or the production time. This type is appropriate when purchasing new equipment or materials or enlarging of facilities not possible to do [2].

In assembly line balancing various objectives are considered. The goal is to optimize one or more objective without exploiting the assembly line restrictions. The specific objectives of the research work are-

- Minimizing idle time
- Making the production line flexible and decrease the cost
- Minimization of the cycle times
- Better utilization of floor space of a company
- Variety of products in a timely and cost effective manner

In order to carry out this research work, steps that are going to be followed can be outlined as below -

- Collecting information about different types of methods used in line balancing such a MILP, studying different articles
- Collecting related all data of line balancing from a garments industry
- Gathering suitable knowledge on developing an objective function and relatedconstraints
- Using MATLAB to program the function toprove thees timated functionalities of ourmain objective

This thesis can be performed in several other companies with a similar setup and verify from the case studies if the same line balancing criteria are desired in the new setups too. This will also increase the validity and reliability of the research work.A complete set of line balancing criteria can be listed under one research for different line balancing scenarios such as the combinations of Mixed Model, Single Model, Single Sided, Double Sided, Straight Type, U-Type.

2. Literature Review

Assembly line balancing was further introduced to mixed model from single model and it was done by in 1970. Thomopoulos suggested combining precedence diagram of several models of the same product into a combined precedence diagram [3]. A heuristic for solving mixed-model line balancing problems with stochastic task durations and parallel stations was suggested byFrazierb. Frazierb modified previous model and organized new model for assigning tasks to work center [4]. This model applied for six different line balancing problem and simulated resulting layouts and analyzed performance results. WhileGokce suggested goal programming approach to mixed-model assembly line balancing problem. Gokce proposed this model which provide flexibility to the decision maker [5]. On the other hand, comparative evaluation of assembly line balancing heuristics has been developed [6]. In this paper they have discussed about line balancing types. A hybrid genetic algorithm approach to mixed-model assembly line balancing has been developed [7]. The application of Genetic algorithm has been studied widely there. Akpinar, Bayhan & Baykasoglu have proposed a mixed-model assembly line balancing problem with sequence dependent setup times between tasksvia hybridizing ant colony optimization [8]. Simaria & Vilarnho have developed a genetic algorithm-based approach to the mixed-model assembly line balancing problem of type II [9]. Moreover, they discussed about minimizing the number of workstations for a given cycle time and also minimizing the cycle time for a given number of workstations. Özcan & Toklu developed a tabu search algorithm for two-sided assembly line balancing [10]. They solved a combinatorial optimization problem by using tabu search. Yagmahanused multi objective ant colony optimization approach for mixed model assembly line balancing [11]. It was mainly designed for a production plan which is push based. Meanwhile, two sided assembly line balancing using ant colony based heuristic was suggested byBaykasoglu & Dereli [12]. Kucukkoc et al. have suggested a mathematical model and artificial bee colony algorithm for the lexicographic bottleneck mixed-model assembly line balancing problem [13]. This model is referred to as type-1 and type-2 problem. LBMALBP is promoted for the first time in the literature with the help of mathematical model and it also coded with the help of game solver and also optimal solutions are available in the literature for some scale test problems.Alghazi & Kurz have developed mixed model line balancing with parallel stations, zoning constraints, and ergonomics with mixed integer linear programming which was the first paper related to this programming [14]. A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem was developed by Gamberini, Ã, & Rimini [15]. It deals with minimization of labor cost and task re-assignment. They proposed a solution on workload re-assignment and implement cost factors effects which is affected by task movements.Hamta et al. suggested a hybrid PSO algorithm for a multi-objective assembly line balancing problem with flexible operation times, sequence-dependent setup times and learning effect. They considered three objectives for develop this model [1]. One objective was minimizing cycle time, another was minimizing equipment cost and last one was minimizing smoothness index. They used two methods for solving this problem. One was PSO and another was VNS. Meanwhile, in which situation which model is suitable is proposed byBoysen et al. [16]. For robust time and space assembly line balancing under uncertain demand Chica et al. have developed a model [17]. Morshed & Palashsuggested a model to Improve Productivity using Work Sharing Method in Apparel Industry. They focused to improve overall efficiency of single model assembly line by reducing the non-value-added activities, cycle time and distribution of work load at each work station by line balancing. In this model, it includes some calculation about cycle time of processes, identify which things are non-value-added workers or activities, how much workload should be in a workstation with calculation and what should be the proper distribution of workload on each workstation in line balancing [18]. And by this, they tried to improve the productivity and efficiency of the line. Particle swarm optimization algorithm to mixed-model two-sided assembly line balancing was developed byDelice & Kızılkaya [19]. After that balancing and cyclically sequencing synchronous, asynchronous, and hybrid unpaced assembly lines was recommended byLopes et al., [20]. Ramezanian & Ezzatpanahproposed worker assignment problem for multi model assembly line balancing [21]. A genetic algorithm for the multi-objective optimization of mixed-model assembly line based on the mental workload was developed byZhao et al., [22]. Zahiri et al., have developed an MCDA-DEA approach for mixed-model assembly line balancing problem under uncertainty. They worked for U-shaped mixed model assembly lines and a new model was developed which was bi-objective model that helped to minimize total cost, task duplications, zoning constraints, workload of stations. From the literature review, it is clear that there is still opportunity to improve line balancing problem [23]. The main objective of this paper is to modify the existing layout of a Polo-shirt and T- shirt by using mixed model assembly line balancing problem in terms of minimize workstations and minimize cost

3. Methodology

3.1. Model Formulation

Mixed Integer Linear Programming (MILP) are linear programs in which some variables are required to take integer values and arise naturally in many applications. The integer variables may come from the nature of the products. Mixed Integer Linear Programming are solved using the same technology as integer programs [24]. Mixed Integer Linear Programming maximizes or minimizes a linear objective function subject to one or more constraints. MILP adds one additional condition that at least one of the variables can only take on integervalues.Mixed Integer Linear Programming is an optimization technique which is used to generate the optimal or near optimal solutions for a problem. The technique finds broad use in operations research. It is normally use to solve the optimization problems in research, projects and experiments from a given data set. By using MILP, optimization refers that making something better or making a process better. In a process, there are a set of inputs and outputs. So optimization through MILP refers setting the values of input in such a way that will help to find the best output or result [24].

In this case, there are two model (J_1, J_2), J_1= for the T- shirt and J_2= for the Polo shirt. So, a mixed model assembly line is proposed for those two product models which will be more cost effective, reduce the space requirements, labors than two single line assembly [25].

3.1.1.Objective Function

There are two objective functions.The first objective function is for the mixed model cycle time of the processes when workstations is constant, will be-

$$F_1 = \sum_{s=1}^{s} \sum_{j=1}^{j} C_t \tag{1}$$

Where,

F_1= Objective function

C_t= Total cycle time of tasks

j = Total number of models

s = Number of workstations

The second objective function is for resources,

$$F_2 = \sum_{s=1}^{s} \sum_{r=1}^{\max_r} Y_{rs} \tag{2}$$

Where,

Y_{rs} is binary, if the resourceis used in workstations then it will be 1; otherwise it will be 0.

F_2 = objective function

r = Number of Resources (Helpers)

max_r= maximum resources =1, 2,…….23

3.1.2. Constraints

In this model, there are three constraints. The sum of all task times assigned to each workstation (t_i) should be equal or not exceed the cycle time are ensured by constraint (3),

$$\sum t_i \left(X_{es} \right) \le C_t \tag{3}$$

Where, X_{es}= 1 if task is assigned in that workstation, otherwise 0.

C_t= total cycle time of tasks

t_i= total task time for a specific model

All precedence requirements must be assigned by constraint (4),

$$\sum_{s=1}^{s} X_{as} - \sum_{s=2}^{s} X_{bs} \le C_t \tag{4}$$

Where,a, b is the sequences of tasks.

Constraints (5) denotes Each task can only be assigned on one workstation.

$$\sum_{s=1}^{s} X_{es} = 1 \tag{5}$$

Where, X_{es}= 1 if task is assigned in that workstation, otherwise 0.

3.2. Existing Model for T-Shirt

From the layout of t-shirt we came to know that there were 19 processes to make a complete t-shirt. 10 operators and 10 helpers were needed to run the line without creating any bottleneck.The first operation of t-shirt was to match the front and back part. One helper did the matching. Operation time and capacity of helper was measured and the line was well balanced. After matching the front and back, then it went through all the processes one by one. Shoulder joint which is the second process done by single needle machine. Then the neck joint is done. Back piping is given on the neck to protect that area from sweat. Every single t-shirt contains a label. After finishing back piping a helper marks the area where the main label will be attached. Main label indicates the size of the t-shirt.An operator stitches the main label to the marked area. Then a helper matches the exact sleeves required for the bodies. Sleeve is joint to the body by using O/L machine. The last part of sleeve requires an extra stitching called sleeve heam and it is done by F/L machine. Side joint means the stitching of body side. Then sleeve tuck is given to by S/N machine. Then body heam is done by F/L machine. Moreover 'V' neck is given according to buyer's requirement. When all these processes are done then it goes for trimming and Q/C pass. It took 5.25 minutes to complete a single t-shirt. The expected output was 175 pieces per hour.

3.2.1. Time Study

Observed time (OT): The observed time is the average of the recorded times [26].

$$OT = \frac{\sum x_i}{n} \quad (6)$$

Where, $\sum x_i$= Sum of recorded times,n = Number ofobservations.

Performance Rating (PR): Performance rating is given to a worker based on how efficient he/she is compared to standard worker (in 100%). Generally, it is based on nature, type of work and skill of the worker. For standard purpose, 90% rating is taken in thisreport.

Normal Time (NT): The normal time is the observed time adjusted for worker performance. It is computed by multiplying the observed time by a performance rating (PR), NT = OT × PR

Standard Time (ST): The standard time for a job is the normal time multiplied by anallowance factor (AF) [26].

ST = NT × AF Where, AF = 1 + A, A = Allowance percentage based on job.

3.2.1.1. Sample Time study of the workstation 4 for T-shirt:

Time study have been performed for all the workstations. A sample time study for the workstation 4 where the operation back piping is done has been shown in Table 1. Here, 10% allowance factor has been considered. And, based on the expertise of the assigned worker the performance rating has been taken as 90%.

Table 1. Time study for performance rating for T-shirt

Work station 04	Observations (In Seconds)					Performance Rating
	1	2	3	4	5	
Back piping	14.9	15	15.1	15	14.9	90%

OT = (14.9+15+15.1+15+14.9) / 5 = 14.98 sec = 15 sec
NT = 15 ×0.90 = 13.5 sec
AF = 1+ 0.10 = 1.10
ST = 13.5 × 1.10 = 14.85 sec

In Table 2, the calculated standard time and machine required for each workstation for T-shirt has been shown. Moreover, the production per hour of each workstations has also been shown in the Table 2.

Table 2. The data table of T-shirt

Workstations	Processes Name	Resource type	Standard time (sec)	Production per hr.
1	Back and front match	Helper	15	220
2	Shoulder joint(2)	O/L	30	110
3	Neck joint and cutting	O/L	16.8	196
4	Back piping	F/L	15	220
5	Main label mark	Helper	10.8	305
6	Label joint	S/N	13.8	239
7	Sleeve body match	Helper	16.2	203
8	Sleeve joint (2)	O/L	30	110
9	Sleeve heam	F/L	16.2	203
10	Side joint(2)	O/L	18	183
11	Sleeve tuck(2)	S/N	16.2	203
12	Body heam	F/L	16.8	196
13	V neck	S/N	16.2	203
14	Trimming (2)	Helper	30	110
15	Quality check pass	Helper	18	183
16	Ironing	Helper	18	183
17	Measurement	Helper	13.8	239
18	Price tag	Helper	16.2	203
19	Packing	Helper	18	183

Sketch view of t-shirt with operationnames shown in Figure 1:

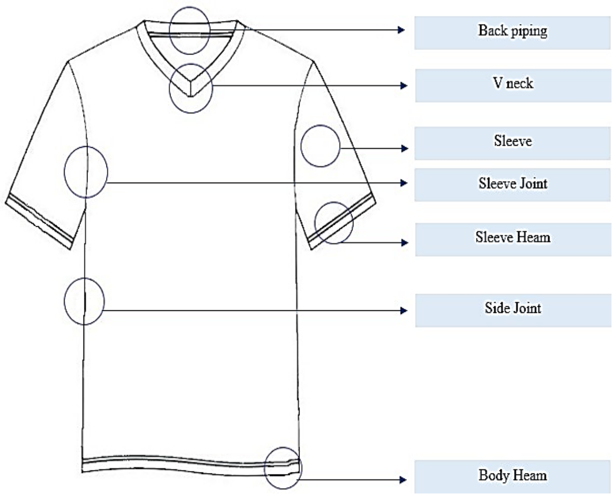

Figure 1. Different parts of a T-shirt

In Figure 2, the current layout for the T-shirt present in the garments factory has been shown.

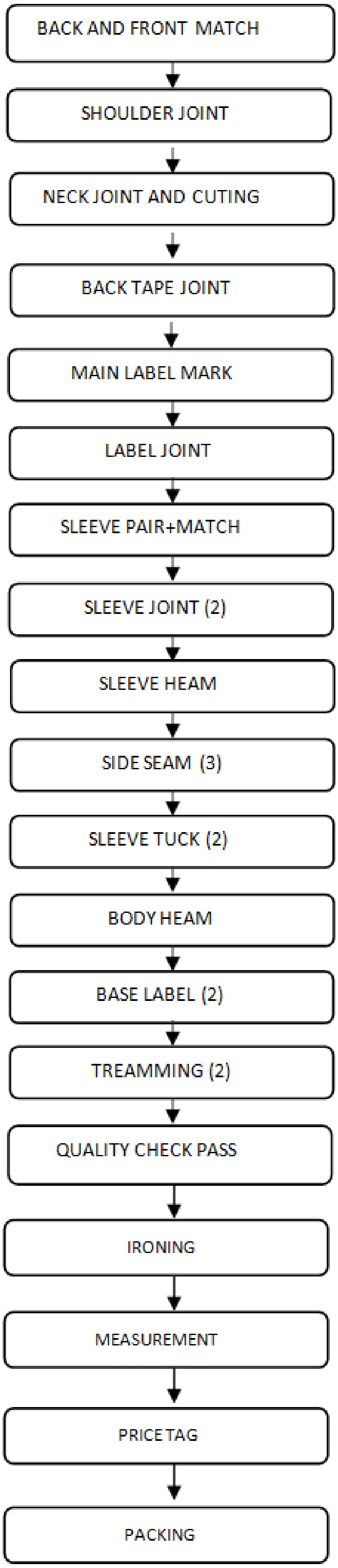

Figure 2. Current layout of T-shirt line

Precedence diagram for T-shirt production is shown in Figure 3.

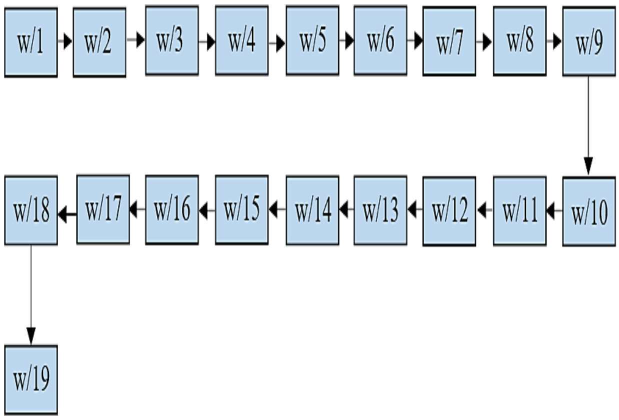

Figure 3. Precedence diagram for T-shirt production line

There are 19 workstations. Now, the capacity balancing for t-shirt assemblyline is shown in Figure 4.

This is the graphical presentation of target production per hour and production per hour. The red line in the middle indicates the target production per hour which is 175. Along X-axis these are the operation names in every station. The blue line in the graph indicates the production per hour. The blue line is fluctuating from station to station because the production capacity differs in every station. From this graph we can find out where is the bottleneck is occurring. There it indicates that in some workstation, the production rate is below than the tar get value which is 175 perhour. So, in those workstation ssuchass houlder joint, sleevejoint, trimming there are used two operators in each workstation to achieve the targetdemand.

3.3. Existing Model for Polo Shirt

There was another line for polo shirt. It was actually one and a half line. The space of the floor was not suitable to set up all the machines in one line. So they used one full line and another half line to complete the layout. The process of polo shirt making was some different than t-shirt making. There were some extra operations in polo shirt making. The main differences of polo and t-shirts were the placket, collar and the buttons. In these operations' polo shirt had to use some pre-processes. As there were some extra operations, operator and helper number was also increased. The industry had to use dedicated lines for each model. We have described lot of processes in T-shirt operation description which is also similar in Polo Shirt. Rest of the processes of polo shirt which are not similar are described below:

3.3.1. Time Study for Polo Shirt

A sample calculation for time study for polo shirt is shown in Table 3 for workstation number 4.

Table 3. Time study for performance rating for Polo-shirt

Work station 04	Observations (In Seconds)					Performance Rating
	1	2	3	4		
Shoulder joint	34	37	34.5	35.5	37	90%

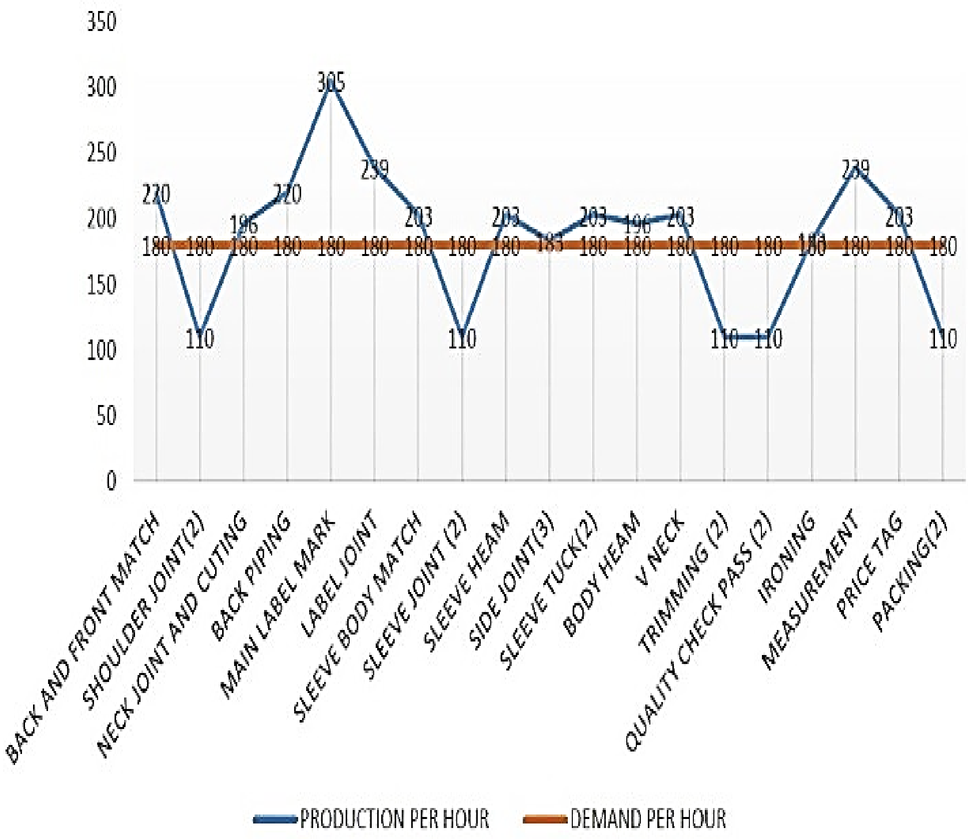

Figure 4. Graphical representation of production rate of T-shirt

Table 4. The data table of Polo-shirt

Workstations	Processes name	Machine type	Standard time (s)	Targets per hr.
1	Placket position mark	Helper	18	183
2	Lower placket joint	S/N	15	220
3	Upper placket joint	S/N	15	220
4	Back front part match	Helper	15	220
5	Shoulder joint(2)	O/L	36	91
6	Care label attach	S/N	10.8	305
7	Collar tuck	S/N	16.8	196
8	Collar joint	O/L	16.8	196
9	Twill tap attach	S/N	16.8	196
10	Placket mark scissoring	Helper	10.25	321
11	Placket inside close	S/N	18.3	180
12	Placket outside close	S/N	18.3	180
13	Placket attach inside	S/N	18.65	176
14	Bottom heam	F/L	16.8	196
15	Cuff servicing	O/L	13.8	239
16	Sleeve cuff joint(2)	O/L	24	137
17	Body + sleeve match	Helper	16.2	203
18	Sleeve joint (2)	O/L	30	110
19	Side seam(2)	S/N	36	91
20	Twill tape attach	S/N	16.8	196
21	Buttonhole	Bar tech	16.25	203
22	Button position mark	Helper	12	275
23	Button attach	CNC	18	183
24	Button insert	Helper	15	220
25	Trimming(2)	Helper	30	110
26	Quality pass check	Helper	18	183
27	Ironing	Helper	18	183
28	Measurement	Helper	13.8	239
29	Price tag	Helper	16.2	203
30	Packing	Helper	18	183

OT = (34+37+34.5+35.5+37) / 5 = 36 sec (approx.)
NT = 36 × 0.90 = 32.4 sec
AF = 1+ 0.10 = 1.10
ST = 11.25 × 1.10 = 35.64 sec.

The data for Polo-shirt is given in Table 4.

Sketch view of polo shirt with operationnameshave been shown in Figure 5 and Figure 6.

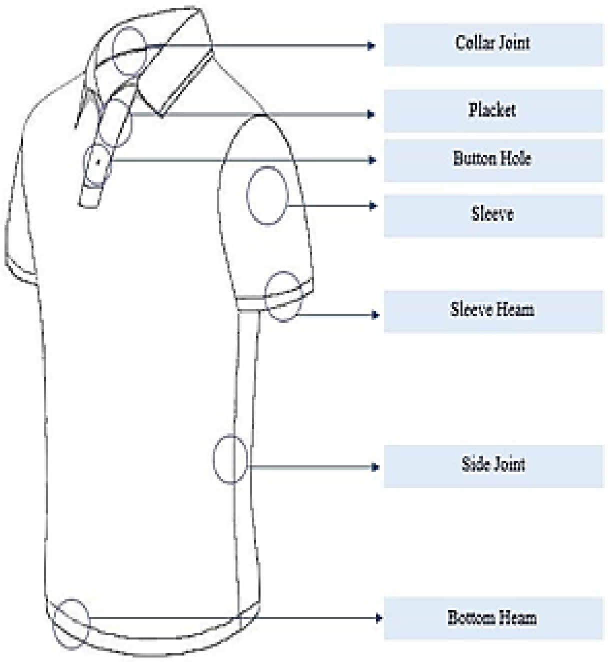

Figure 5. Different parts of Polo-shirt (Front View)

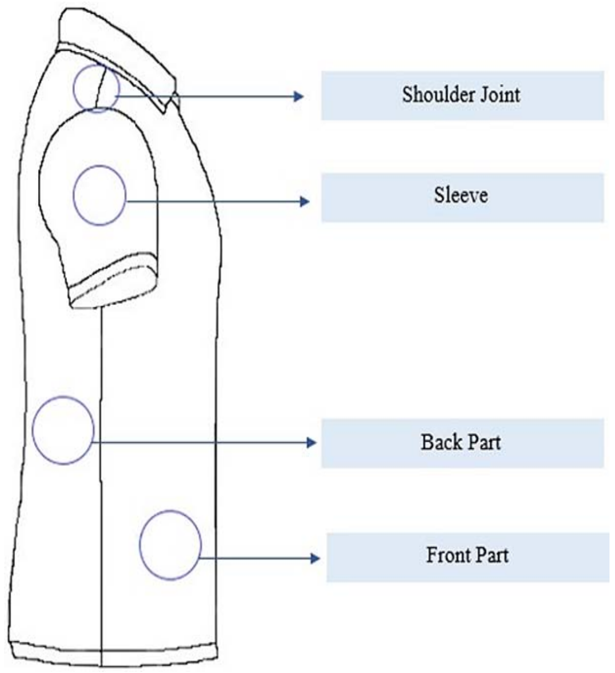

Figure 6. Different parts ofPolo-shirt sketch (Side View)

In Figure 7, the present layout for the polo shirt has been shown according to the workstations. The workstations are named based on the operation performed in that workstation. There are total 30 workstations required for the polo shirt. And, the precedence diagram of polo shirt production has been shown in Figure 8 for these 30 workstations.

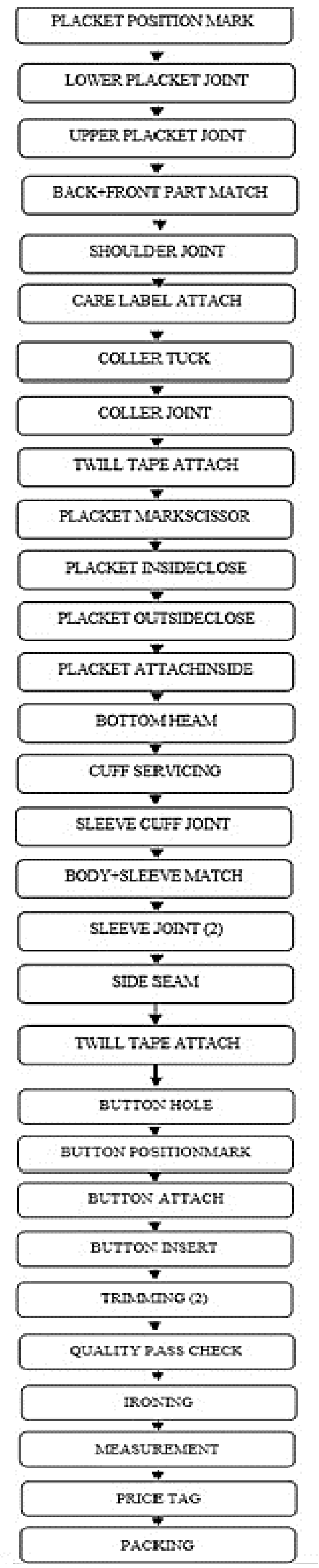

Figure 7. Current layout of Polo-shirt

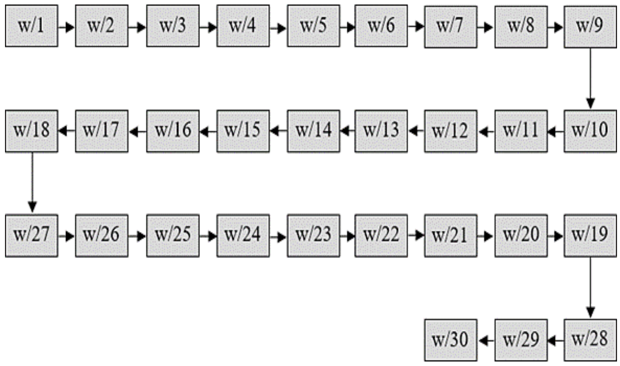

Figure 8. Precedence diagram for Polo-shirt production

There are w/1,2,3…..30 = Workstations.

This is the graphical presentation of target production per hour and production per hour. The red line in the middle indicates the target production per hour which is 175. Along X-axis these are the operation names in every station. The blue line in the graph indicates the production per hour. The blue line is fluctuating from station to station because the production capacity differs in every station. From this graph we can find out where is the bottleneck is occurring. Fromthegraph, we canseethat, there aresomeworkstationwhich creates bottleneck. Such as, shoulder joint, sleeve cuff joint, sleeve joint, side seam, quality pass check, packing. In those workstations, the production rate is below than the target value. For the capacity balance, two operators are assigned in each workstation to achieve the targetvalue.

3.4. Proposed Model

We have visited a "T" shirt and "Polo" shirt manufacturing company. They have two different assembly lines for "T" shirt and "Polo" shirt production. Because of those two different assembly lines for "T" shirt and "Polo" shirt which were running improperly and ineffectively. So, their efficiency was too low and cost was huge. As this company produced "T" shirt and "Polo" shirt in different assembly lines and there were less differences between those two product processes, so "Mixed Model Assembly Line Balancing" with Mixed Integer Linear Programming(MILP).

3.4.1. Formulation of Mixed Integer Linear Programming (MILP):

Mixed Integer Linear Programming (MILP) are linear programs i which some variables are required to take integer values and arise naturally in many applications. The integer variables may come from the nature of the products. Mixed Integer Linear Programming are solved using the same technology as integerprograms.Mixed Integer Linear Programming maximizes or minimizes a linear objective function subject to one or more constraints. MILP adds one additional condition that at least one of the variables can only take on integer values.(Antunes et al., 2004)Applications of Mixed Integer Linear Programming (MILP): Mixed Integer Linear Programming (MILP) are being used to solve a wide variety of problems in garments right from production of fibers to apparel design and manufacturing.Optimization - Mixed Integer Linear Programming are most commonly used in optimization problems wherein we have to maximize or minimize a given objective function value under a given set of constraints. The approach to solve Optimization problems has been highlighted throughout thepaper. The data and layout of mixed model is given in Table 5.

Table 5. The data table of mixed model

Workstations	Processes name	Machine type	Standard time (s)	Production/hr.
1	Placket Position mark	Helper	18	183
2	Placket attach(2)	S/N	30	110
3	Placket inner tuck	S/N	15	220
4	Back/front match	Helper	15	220
5	Shoulder joint(2)	O/L	36	91
6	Label mark	Helper	10.8	305
7	Label joint	O/L	13.8	239
8	Collar tuck	S/N	16.8	196
9	Collar/neck joint	O/L	16.8	196
10	Twill attach/back piping	S/N	16.8	196
11	Cuff servicing	O/L	13.8	239
12	Sleeve cuff attach(2)	O/L	24	137
13	Sleeve match	Helper	16.2	203
14	Sleeve joint(2)	O/L	30	110
15	Side seam + care label add	S/N	18	183
16	Side seam	S/N	15	220
17	Bottom heam	F/L	16.8	196
18	Placket mark	Helper	10.2	323
19	Placket in/out side close(2)	S/N	36.6	90
20	Placket attach inside	S/N	18	183
21	Button hole	Bar tech	16.2	203
22	Button mark scissoring	Helper	12	275
23	Button attach	CNC	18	183
24	Sleeve heam	F/L	16.2	203
25	Sleeve tuck	S/N	16.2	203
26	"V" neck	S/N	16.2	203
27	Button insert + thread cut(2)	Helper	30	110
28	Quality check pass	Helper	18	183
29	Ironing	Helper	18	183
30	Measurement	Helper	13.8	239
31	Price tag	Helper	16.2	203
32	Packing	Helper	18	183

In Figure 9, the layout of the proposed mixed model is shown.

In Figure 10, the precedence diagram of the proposed mixed model assembly line is shown.

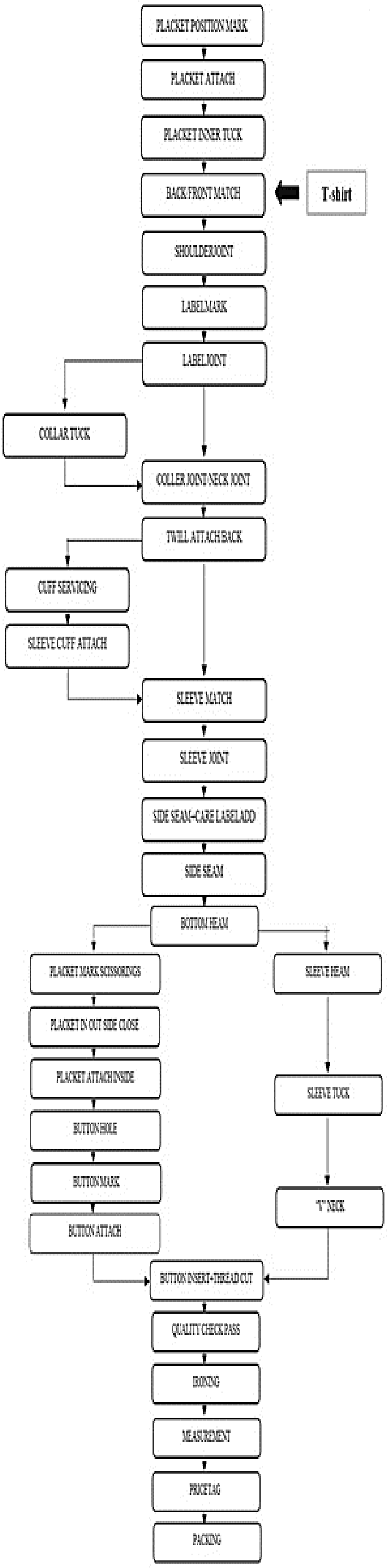

Figure 9. Proposed layout of Mixed Model

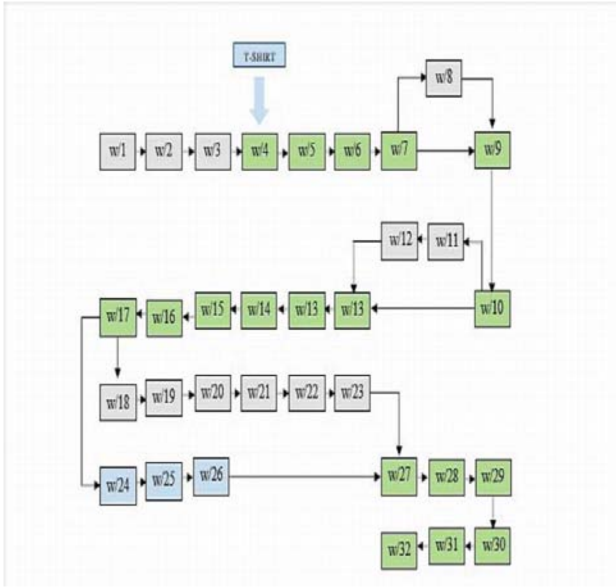

Figure 10. Precedence diagram of proposed mixed model assembly line

This is the graphical presentation of target production per hour and production per hour. The red line in the middle indicates the target production per hour which is 175. Along X-axis these are the operation names in every station. The blue line in the graph indicates the production per hour. The blue line is fluctuating from station to station because the production capacity differs in every station. From this graph we can find out where is the bottleneck is occurring. In the mixed model, we proposed a line in which it can be produced both T-shirt and Polo shirt. There are some similar processes which is merged in an assembly line to produce two models (Polo shirt and T-shirt) in an assembly line. So, the graph refers the production rate per hour and also indicates the possible workstations in which bottleneck can be occurred. It refers that, in placket mark, shoulder joint, sleeve cuff attach, sleeve joint, placket inside or outside close, button insert and thread cut those requires two operators in each workstation to achieve the target value 175 products per hour.

4. Result and Findings

4.1. Cost Optimization and Increase in Productivity

To remain competitive, all the companies must offer quality products at cutthroat prices. To make this possible, a company can cut their manufacturing cost per unit and increase productivity with the same amount of input. There are four best ways that can help an industry to reduce costs and increase productivity are-

- Optimization of work flow
- Reducing laborcost
- Installing modernmachines
- Reducing materialcost

In our scenario the industry is using dedicated line for each product. That results in more worker and helper. Firstly, we designed a work flow optimization. The new optimized model helps to reduce the number of helpers. Lessnumber of helpers means less cost in every line.

That isoneway we have optimized thecost.As we have also optimized the space, we have implemented more lines in one floor. Thus, the number of lines in the floor increased and despite being the output is same from the lines but overall production has increased.

4.1.1. Space Optimization

This paper proposes a new method for optimizing garment production unit design by estimating more suitable values of ease allowance using single model to mixed model assembly line balancing. In the garment in dustry, an apparelmanu facturer is interested in whether as sembly work will be finished on time for delivery and increasing machine or laborutilization. We observed that there are two individual production units for Polo shirt & T-shirt in this garments industry. By using mixed model assembly line balancing we have successfully minimized the space. A compromise between Polo shirt & T-shirt is set up in the aggregated value of ease allowance as well as the corresponding garment pattern. In this way, we proposed only one production unit for both Poloshirt & T-shirt. The proposed methodcan effectively reduce huge space. Compared with the classical design methods, the proposed method is more suitable and more adaptive to the current competitive international garment market, which requires more and more personalized products meeting human comfort and stylevariation.

4.1.2. Resource Optimization

To optimize the resources, we observed the amount of resources (Helper) need in the single assembly line of polo shirt and t-shirt. In single assembly line of T-shirt, there are some workstation in which helper works as a workstation. And also, in Polo shirt assembly line, there are some workstation in which helper works as a workstation. We observed that in those two lines, there are some process which are similar with each other. So, we proposed a mixed line where those similar processes can be merged. Which will help to reduce the number of workers, especially helpers.So, after merged them, in the mixed model line, the target demand which is 180 piece per hour can be fulfilled by only 12 helpers. Where in single T-shirt assembly line and Polo shirt assembly line, the number of helpers is respectively 9 and 12. So, total number of helpers was 21 in previous. But in mixed model assembly line, number of helpers is 12. So, it can optimize the requirement of helpers (Resources). Therefore, by minimizing the number of required helper, the company can reduce its expenditure. Moreover, by employing the resources to the suitable workstations based on the optimization results will ensure better utilization of resources and reduce the overall slack. Again, as the number of helper have been reduced and assigned to the suitable workstation, the material handling will be more efficient. This will ensure less idle time. Ultimately, the rate of production will increase in the long run. An assignment of resources or helpers to different workstations has been shown in the Table 6. In Table 6, a relative comparison has been shown among the resources used by the present layout as well as resources assigned in our proposed mixed model.

4.1.3. Comparison of tangible benefits before and after line balancing

Table 6. Comparisons of resources (Helpers) require in before and after line balancing

No of workstations	Sequences of task	Resource uses for t-shirt	Resource uses for polo shirt	Resource uses for mixed model
1	1	0	1	1
2	2	0	0	0
3	3	0	0	0
4	4	1	1	1
5	5	0	0	0
6	6	1	1	1
7	7	0	0	0
8	8	0	0	0
9	9	0	0	0
10	10	0	0	0
11	11	0	0	0
12	12	0	0	0
13	13	1	1	1
14	14	0	0	0
15	15	0	0	0
16	16	0	0	0
17	17	0	0	0
18	18	0	1	1
19	19	0	0	0
20	20	0	0	0
21	21	0	0	0
22	22	0	1	1
23	23	0	0	0
24	24	0	0	0
25	25	0	0	0
26	26	0	0	0
27	27	2	2	2
28	28	1	1	1
29	29	1	1	1
30	30	1	1	1
31	31	1	1	1
32	32	1	1	1
	Total	10	13	13

Our contributions and benefits before and after line balancing are shown in Table 7. Here, the comparisons has been done on the basis of resources, space and cost. In Table 7, a percentage of change has also been shown.

Table 7. Comparison between Existing and Proposed Model

No	Parameters	Current	Proposed	Change	% of change
1	Resource	23 persons	13 persons	10 persons	43%
2	Space	1500 sqft	900 sqft	600	40%
3	Cost	330000 BDT	270000 BDT	60000 BDT	18%

4.1.4. Calculation for space requirement

For dedicated t-shirt line the space required is
No. of table*table length* table width = 20*6*5 sqft
= 600 sqft
For dedicated polo shirt line the space required is
No. of table*table length* table width = 30*6*5 sq ft.
= 900 sq. ft.

Total space required = (600+900) sqft
= 1500 sqft
For proposed model total space required is:
No. of table*table length* table width = 30*6*5 sqft
= 900 sqft
Calculation for cost requirement
For current model the cost required is
Resource (helper) * monthly salary + operator * monthly salary
=23*6000 + 24*8000
=3,30,000 taka
For proposed model the cost required is
Resource (helper) * monthly salary + operator * monthly salary
=13*6000 + 24*8000
= 2,70,000 taka

5. Conclusion

In this mixed model line balancing, there are some benefits like less work stations, less workers, less time is required to produce a Polo shirt or T-shirt. In garments industry, we can see that most of the garments use an assembly line to produce a single product. But there are lots of processes in the assembly line to produce the single product which are similar to the other product processes. But they use different lines to produce those products. So, we think that a mixed model line assembly can be more cost efficient more than a single model line assembly. It can be reduce the production cost, the workstations, and also reduce the number of operators and helpers. It can be helpful to maximize the utilization of floor space.If we can use the mixed model line assembly in a floor, then it can be save the other single line assembly line spaces which are now uses separately to produce products. After implementation of mixed model, we can use this space for other production. We can use the mixed model line assembly for the combination T-shirt and Polo shirt batch in which the thread can be used in both T-shirt and Polo shirt.From this mixed model, we can be able to achieve our requirements. Like-The line can produce our current demand of 175 products per hour. It can produce both T-shirt and Polo shirt. So, it reduces the requirements of available floor space in the factory. It can reduce the cost by reducing the work stations, cycle time, idle time and worker. It makes each worker skilled so that the optimum improvement, efficiency and productivity can be achieved.

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