Line Balancing Techniques for Productivity Improvement

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Abstract: **Assembly Line Balancing is the problem of assigning operations to workstations along an assembly line; in such a way that the assignment be optimal in some case. The minimization of the number of workstations and maximization of the production efficiency are the most common goals in the line balancing. In this article two heuristic approaches are applied which are Ranked Positional Weight and largest candidate techniques. And also reviews of different article in the area of assembly line balancing techniques and tries to find out best techniques. The aim of this article is focusing on increasing the accuracy of standard time by time study and rearranging the work arrangement among the operators and work stations through line balancing techniques and comparison of the efficiencies and delay times in two techniques which are applied in the garment industry for the purpose of solving garment problems. By taking different consideration like, number of stations, task time and cycle time to reach final conclusion.**

Keywords: **Assembly Line balancing, Line balancing techniques, and standard time.**

1. INTRODUCTION

The textile and garments industry is one of the largest in the world. As one learns about the various aspects of textiles and garment production, it is apparent that it plays a major role in the economy of a country. The textiles and clothing contribute to employment in developed countries, particularly in regions where alternative jobs may be difficult to find and in the European Union. Countries some of which have experienced a very high output growth rate in the sector (e.g. Bangladesh, Sri Lanka, Viet Nam and Mauritius). It has become an economic force to reckon with and employs a lot of people. It is in light of this among others that the government of Ghana has set up the Gold Coast Garment. The large scale manufacturing firms were expected to be 10 in all employing 10,000 Ghanaians over a four year period. The medium sized ones were expected to be 25 employing 12,500 Ghanaians (Rosemary Quarcoo, 2013).

The textile and garment industry is one of the rising sectors in Ethiopia. It is one of the developmental sectors that are given a due attention by the government in the second Growth and Transformation Plan II (GTP II). Aspiring to increase the export from the sector by one billion USD by the end of GTP II, the government is demonstrating commitment in investing in the sector (Tibebu and Henok, 2016). The sector is also expected to create more than 300,000 jobs during the plan period. The progress of the sector is promising; the export status accelerated from 7 million in 1990 to 111 million USD in 1998. Moreover, the national export has been growing from 0.9 to 3.8 per cent. However, some inconveniences remain to be challenging to the progress of the sector (Tibebu and Henok, 2016).Nowadays garment industry makes a significant contribution to national economy in many developing countries. Those countries are exploiting this industry to earn valuable foreign exchange by exporting garment products for their economic growth. Likewise, garment manufacturing firms in Ethiopia should improve overall performance to cope up with the continual stiff competition of the international market. The major stumbling block of Ethiopian garment industry for global competitiveness is low productivity performance (Daniel Kitaw, 2010).In the garment industry sewing section consists of a set of workstations in which a specific task in a predefined sequence is processed. In general, one to several tasks is grouped into one workstation. Tasks are assigned to operators depending on the constraints of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line (Hsinchu, 2014).

Problem statement

Lucy Garment industry is one of the newly established garment manufacture company in Ethiopia. Here in this company Stitching section line-3 is studied only for one sample model which is men's T-shirt for regular size, fabric type polyester and men t-shirt and the main problem of this line is to attaining the targeted production plan. Therefore, the company to attain this target plan, overtime work is conducted and due to this increases the production costs and reduces company profit.

The company targeted plan of men's T-shirt is 1000 shirts per day but the actual output (average per day) is 850 shirts per day produced. The company observations and time study investigation show that the main cause for this is unbalanced assembly line and lack of standard time for each operation due to this the company produced below the target plan.

Therefore, by using line balancing techniques through time study is essential to identify bottlenecks operation, to enhance system performance in terms of productivity and minimizing delay time, and at the same time keeping productivity high.

Objective of the study

The general objective of the paper is improving the productivity through line balancing techniques by increasing line efficiency and giving standard time for each work stations with time study to attaining target plan of the company.

2. LITERATURE REVIEW

Assembly Line Balancing or simply Line Balancing (LB) is the problem of assigning operations to workstations along an assembly line in such a way that the assignment be optimal in some sense. Ever since Henry Ford's introduction of assembly lines, line balancing has been an optimization of production line problem to increase efficiency. The difference between an optimal and a sub-optimal assignment can yield economies (or waste) reaching millions of dollars per year (Falkenauer, unkown). The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man of machine can be minimized. Line balancing aims for grouping the facilities or workers in an efficient pattern in order to; obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes (Mahto, Naveen Kumar & Dalgobind, 2013).

The fundamental of line balancing problems is to assign the tasks to an ordered sequence of stations, such that the precedence relations are satisfied and some measurements of effectiveness are optimized. According to (Pianthong1), 2007) minimize the balance delay or minimize the number of work stations is one of the importance of line balancing techniques. The assembly line balancing problem has received considerable attention in the literature, and many studies have been made on this subject since 1954 (S. H.Eryuruk et al, 2006).The Largest Candidate, Kilbridge and Wester (column) and Ranked Positional Weights (RPW) are different heuristic methods commonly utilized in line balancing of bottleneck workstations and operations and also to arrange and distribute the description element time along the workstations in the system. Each of those methods could be results in a different type of workstations layout (P.Jaganathan, V., 2014).

Line balancing Techniques used in different Articles

Table 1: Name of authors, title of articles, simulation approaches and heuristic algorithm

No	Name of authors	Title of articles	Simulations approaches	Heuristic algorithm
1	vrittika v pachghare , r. s. and dalu	assembly line balancing methods		largest candidate rule (lcr) method, kilbridge and wester column (kwc) method and ranked positional weight (rpw) method
2	Patrick R. Mcmullen1and Peter Tarasewich	Using Ant Techniques To Solve The Assembly Line Balancing Problem	Heuristic Presented Here Works By Simulation.	
3	Santosh T. Ghutukade1 , Dr. Suresh M. Sawant	Use Of Ranked Position Weighted Method For Assembly Line Balancing		Ranked Positional Weighted Method

4	Ashish Manoria Reader In Deptt. Of M.E S.A.T.I, Vidisha (M.P.)	Expert System Based On RPW Technique To Evaluating Multi Product Assembly Line Balancing Solution		Ranked Positional Weighted Method
5	Mahmut Kayar, Ykü Ceren Akyalçin	Applying Different Heuristic Assembly Line Balancing Methods In The Apparel Industry And Their Comparison		Hoffman Method, And Ranked Positional Weighted Method
6	Daniel Kitaw, Amare Matebu And Solomon Tadesse	Assembly Line Balancing Using Simulation Technique In A Garment Manufacturing Firm	Model Is Based On Simulation	
7	Waldemar Grzechca	Assembly Line Balancing Problem With Reduced Number Of Workstations		Ranked Positional Weighted Method
8	V. P.Jaganathan	Line Balancing Using Largest Candidate Rule Algorithm In A Garment Industry		Largest Candidate Rule
9	S. H.Eryuruk, F. Kalaoglu, And M. Baskak	Assembly Line Balancing In A Clothing Company		Ranked Positional Weight Technique And Probabilistic Line Balancing Technique

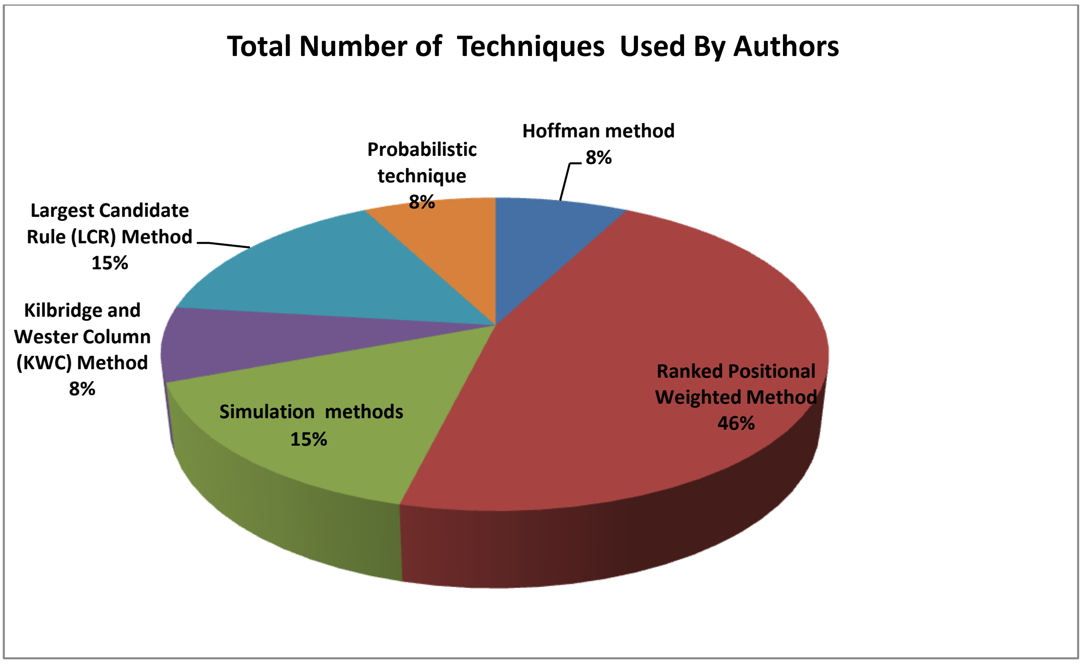

Figure 1: Total Number of Techniques Used By Authors

Therefore, the above figure and articles review investigation most of authors used lines balancing Techniques are Ranked Positional weight (46%) and also simulation approaches (15%) and Largest Candidate Rule (LCR) Method (15%) respectively to improve productivity. The solution steps of Ranked position Weight and largest candidate techniques are explained as follows.

Ranked Positional Weight Technique

Ranked positional weight technique this heuristic method was developed by Helgeson and Birnie of the General Electric Company in 1961 (S. H.Eryuruk et al, 2006). In this method, the ranked positional weight value of each operation is determined.

The procedures below are applied in order to assign operations to workstations (Groove, 2002).

1. The ranked weight value of an operation is obtained by summing the operation time considered with the time of other operations that come after that in series.

2. After all of the ranked positional weights of the operations are determined, they are arranged in decreasing order.

3. Then tasks are assigned to each workstation starting from the task with the highest ranked positional weight. Before this the operation having the second highest ranked value should be selected from the remaining working operations in order to assign to the workstation; the precedence constraints, the operation time, the unused workstation time should be controlled. The assignment procedure is continued until one of conditions below is obtained;

- ✓ If all the operations are assigned to the stations,
- ✓ If there are no operations having either precedence or unassigned time constraints

Largest Candidate Rule Algorithm (LCR)

Known as the main aim of the Line Balance is to distribute the total workload on the assembly line as evenly as possible, despite the reality in which it is impossible to obtain a perfect line balance among the workers. It is then the role of line balance efficiency which is related to the differences in minimum rational work element time and the precedence constraints between the elements. The Largest Candidate Rule accounts for work elements to be arranged in a descending order (with reference to the station time and work elements) to each station value which is not exceeding the allowable preceded (P.Jaganathan, 2014).

Standard Methodology

Standard methodology, involving both direct and synthetic measurement procedures such as time study, work sampling, standard data, predetermined time system and physiological measures, are the measurement tools available to current industrial engineer. From this work measurement tools time study is selected for this study because of ease of use and mostly applicable in manufacturing industries. Average worker: the typical worker, or a worker representative of all workers normally performing the work under study.

Developing standard time

The following procedures and equations have been adopted from (Sharma & Er. Tushar, 2004 s/2006).

1. Take individual time observation for each task.
2. Determine the number of cycles to be timed using a formula with 95% confidence level and 5% accuracy level.
3. If the value of N is more than the sample taken, additional sample has to be taken again.
4. Calculate average actual time by the following formula.

$$\text{Tav} = \frac{Total\ time}{Number\ of\ sample} \quad \text{……………………………………………eq. (1)}$$

5. Find normal time with respect to rating factor (wasting-house system of rating SECC) using. Normal time =average actual time *performance rating factors …………..eq. (2)

6. Calculate the standard time in consideration to allowance.

Using Standard time = normal time + allowance…………………………………eq. (3)

7. Allowance: fixed allowance (personal and fatigue), variable allowance, contingency allowance, and special allowance. Personal allowance: for physical needs like drinking water, taking tea, visiting toilet, and trip to dressing room, Mostly 5% Fatigue allowance**:** for physical or mental tiredness. Common figure is 4%. (ILO1992), Variable allowance**:** add for relaxation. Mostly from (2-3%), Contingency allowance: added for unexpected item of work or delay (1-5%), Special

allowance**:** periodic activity allowance (like maintenance of machine). Not more than 5%, and Allowance range = (15 - 20%).

8. For having 95% confidence level with ±5% accuracy in time study. $N =$

$$\left[\frac{40 * \sqrt{n * \sum(fx^2) - (\sum fx)^2}}{\sum(fx)}\right]^2 \text{...eq.(4)}$$

Line Balancing Steps and Basic Equations

The following procures and questions are adopted from (Jacobs).

1. Specify the sequential relationship among tasks using a precedence diagram. The diagram consists of circles and arrows.

2. To determine cycle time

$$Ct = \frac{\text{production time per day}}{\text{average output per day}} \text{.......................................eq. (1)}$$

3. Determine the theoretical minimum number of workstation (N_t)

$$Nt = \frac{\text{sum of task time}}{\text{Ct}} \text{..eq. (2)}$$

4. To compute efficiency and balance delay of the line.

$$Efficiency = \frac{\text{sum of task times (T)}}{\text{actual number of work stations (Na)} * cycle\ time\ (Ct)} \text{.....................eq. (3)}$$

5. To compute delay time (D)

$$\frac{\text{actual number of station (Na)} * \text{cycle time(Ct)} - \text{sum of task time (T)}}{\text{actual number of work stations (Na)} * \text{cycle time (Ct)}} \text{.......................eq. (4)}$$

6. Smoothness index (SI)

SI= $\sqrt{\sum_{i=1}^{n}[\mathbf{Ct} - \sum(\mathbf{ti} * \mathbf{Xij})]^2}$ ....adopted from eq. (Kumar, June 2012).

Where $t_{i,j}$=cycle time, N=number of work station

Basic Productivity formulas

The following questions are adopted from (Mahto, 2013).

1. To compute efficiency

$$E = \frac{\text{actual output}}{\text{theoretical output}} * 100\% \text{...eq. (1)}$$

2. Theoretical output

$$Theoretical\ output = \frac{\text{No operators} * \text{working hours}}{\text{smv}} \text{........eq. (2)}$$

3. RESEARCH METHODOLOGY

To balance a production line Comparing the productivity and efficiency before and after implementing the balancing technique in line. Considering t-shirt production line selected from the sewing section. One garment order is chosen which was started in that line, style description, and fabric type and color was chosen & necessary data was accumulated from the selected line. Here in this line-3 is studied only for one sample model which is men's T-shirt for regular size and fabric type polyester. First the whole garment activity was analyzed and operational breakdown was created with operational description, process sequence, & machine requirements of the inputs to operating. Then workers were placed to different work stations based on operation sequence, experience of the operators and skills & machine types and a standard time for each job was given to the operators. In the line researcher observing that the output for three day in the company and found that the company can't get the desired output or target output of the company plan which is 1000 shirts per day but the actual output (average output per day) is 850 up to 900 shirts per day. So that researcher try to develop standards time for each operation and individual workers performed by work study method which is sampling techniques and balancing the line by using Ranked positional weight and Largest Candidate techniques to increase the efficiency of the line, productivity, to decrease idle time in the line, to minimizes the bottlenecks and final to meeting the target output of the company

4. DATA ANALYSIS AND DISCUSSION

The aim of this research is to develop standard time and balancing the production line by using Ranked Positional Weight Technique which is defined as the time required by an average worker, working at normal pace to complete a specified task using a normal method.

Table 2: Activity description, number of stations, operation name, Name of operator, Machine type, number of operators and representation codes

NO	Number of stations	OPERATION NAME	Name of operator	MACHINE TYPE	NO. OF OPERATOR	CODES
1	1	Brand label attach on yoke	Eden Asrat	SNLS	1	A
2	1	Back and yoke attach	Desta wubet	SNLS	1	B
3	1	Small placket attach with sleeve	Sara	SNLS	1	C
4	1	Big placket attach with sleeve	Meskerem	SNLS	1	D
5	1	Button hole making on front		BM	1	E
6	1	Pocket attach on left front	Bosen	SNLS	1	F
7	1	Shoulder stitching	Gene	HELPER	1	G
8	1	Collar attaching with body	Emawaysh	SNLS	1	H
9	1	Collar close	Yalembizu	SNLS	1	I
10	1	Sleeve attaching	Lakech	SNLS	1	J
11	1	Side seam stitching	Meseret	SSM	2	K
12	No station	In line checking	Unknown	Manual	1	L
13	1	Bottom hemming	Tigist	SNLS	1	M
14	1	Cuff attaching	Mestewat	SNLS	1	N
15	1	Trimming of bottom of hem	Unknown	SCISSOR	1	O
16	1	Point buttonhole on cuff, band and placket	Genet	MANUAL	1	P
17	1	Button setting	Zewuditu	BSM	1	Q
18	1	Thread trimming	Unknown	SCISSOR	1	R
19	1	Quality check	Unknown	MANUAL	1	S

Observed Time in Lucy Garment Workstations

Table 3: Time study sheet part one

Time study sheet format														
Target per day =1000pcs			size = regular				Men t-shirt					color = cream		
Fabric type = polyester														
NO	OPERATIONS CODE	OPERATER NAME	OSBERATION TIME IN SECOND(PART ONE)											
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T 10	T 11	T 12
1	A	Eden Asrat	9	9	9	7	7	8	7	8	8	7	7	8
2	B	Desta wubet	11	10	9	10	11	10	11	10	9	11	10	10
3	C	Sara	15	14	16	15	14	15	16	15	14	16	14	16

4	D	Meskerem	14	11	13	11	13	12	11	12	13	14	12	13
5	E		14	16	14	16	14	18	15	16	14	14	18	14
6	F	Bosen	12	9	11	11	8	12	13	13	11	9	11	13
7	G	Gene	15	12	17	13	14	11	12	14	11	12	12	11
8	H	Emawaysh	12	13	8	14	11	9	12	11	12	13	14	12
9	I	Yalembizu	9	12	13	9	11	8	13	9	11	12	8	12
10	J	Lakech	14	15	13	14	15	12	13	15	14	12	15	13
11	K	Meseret	26	29	28	28	26	30	29	29	26	30	29	28
12	L	Unknown	25	30	30	28	28	30	28	28	25	30	30	25
13	M	Tigist	30	25	34	36	28	27	25	25	34	25	30	28
14	N	Mestewat	29	27	25	29	25	27	25	25	27	25	25	25
15	O	Unknown	28	27	27	24	23	23	25	27	25	24	23	22
16	P	Genet	26	28	26	28	28	29	26	28	29	29	31	29
17	Q	Zewuditu	27	24	24	27	28	28	23	24	27	23	22	25
18	R	Unknown	12	11	10	12	9	11	13	14	8	13	11	13
19	s	Unknown	20	22	38	22	22	32	30	27	22	20	27	28

Sample-1: Procedures for developing standard time for code A, which is Brand label and attach on yoke activity.

Where t =Task time in seconds for each activity

n = number of stopwatch observation ($\sum \boldsymbol{f}$)

N = minimum number of observation required

f = frequency

1).Brand label and attach on yoke

Table 4: code A, Brand label and attach on yoke

T	F	Fx	x^2	fx^2
8	6	48	64	384
7	3	21	49	147
9	3	27	81	243
Total sum	n = 12	96	194	774

To determine the number of cycles equation eq. (4) is used for having 95% confidence level with ±5% accuracy in time study.

$$N = \left[\frac{40 \, * \, \sqrt{n * \sum(fx^2) - (\sum fx)^2}}{\sum(fx)}\right]^2$$

Where n is the initial number of samples taken

$$N = \left[\frac{40 \, * \, \sqrt{n * \sum(fx^2) - (\sum fx)^2}}{\sum(fx)}\right]^2 N = \left[\frac{40 \, * \, \sqrt{12 * 774 - 96^2}}{96}\right]^2$$

$$N = 12.5 \quad \approx 13$$

$\boldsymbol{N} > n$, this indicates that there should be a need for additional observation (reading) is needed. Therefore, when we observe another 5 additional observations the result will be as follows.

T	f	Fx	x^2	fx^2
7	5	35	49	245
8	6	48	64	384
9	6	54	81	486
Sum =24	n = 17	137	194	1115

$$N = \left[\frac{40 * \sqrt{n * \sum(fx^2) - (\sum fx)^2}}{\sum(fx)}\right]^2 \quad N = \left[\frac{40 * \sqrt{17 * 1115 - 137^2}}{137}\right]^2$$

$$N = 15.85 \approx 16$$

$\boldsymbol{N} < n$ From this, it can be concluded that 16 numbers of observation needed, but it is studied more than that. The result found in appendix two.

Therefore, the actual time is calculated as the average time of the actual observed time. Thus,

$$average\ actual\ time = \frac{total\ \ time\ observed}{total\ number\ of\ observation}$$

$$= \frac{\mathbf{137\ sec}}{\mathbf{17}}$$

= 8.05 seconds.

NT = average actual time × performance rating factor

= (8.05*1.1)

= 8.855 sec

ST = normal time + (allowance)

= (8.855+0.2)

=**9.055 sec**

Standard Time of each Operation

Table 5: summary of standard time for each activity

Task name	Average time in second	Performance rating factors	Normal time in second	Allowances for workers (%)	**Standard time in seconds**	Total number of operators	Task time per number operator
Brand label and attach on yoke	8.05	110%	8.855	20%	9.055	1	9.055
Back and yoke attach	10.28	100%	10.28	20%	10.48	1	10.48
Small placket attach with sleeve	15.11	110%	16.621	20%	16.821	1	16.821
Big placket attach with sleeve	12.56	110%	13.56	20%	14.016	1	14.016
Button hole making on front	15.15	100%	15.15	20%	15.35	1	15.35
Pocket attach on left front	11.61	105%	12.2	20%	12.4	1	12.4
Shoulder stitching	10.31	100%	10.31	20%	10.51	1	10.51
Collar attaching with body	13.58	100%	13.58	20%	13.78	1	13.78
Collar close	10.31	110%	11,34	20%	11.54	1	11.54

Sleeve attaching with body	13.58	110%	14.94	20%	15.14	1	15.14
Side seam stitching	**28.16**	**115%**	**32.384**	**20%**	**32.584**	**2**	**32.584**
In line checking	27.8	105%	29.19	20%	29.39	1	**29.39**
Bottom hemming	10.31	110%	11,34	20%	11.54	1	11.54
Cuff attaching	26.75	105%	28.08	20%	18.28	1	18.28
Trimming of bottom of hem	11.83	110%	13.013	20%	13.213	1	13.213
Point buttonhole on cuff, band and placket	27.86	115%	32.04	20%	32.24	1	**32.24**
Button setting	10.31	110%	11,34	20%	11.54	1	11.54
Thread trimming	11.83	100%	11.83	20%	12.03	1	12.03
Quality check	28.75	100%	28.75	20%	29.95	1	**29.95**
Total sum					Smv=311sec		

The bottleneck in this line after the standard time developed is **side seam stitching** with the highest task time of **32.584** seconds per shirt. Therefore, with the above workload balance, the production capacity of a single line is:-

$$\frac{1\text{ shirt}}{32.584}*\frac{60\text{ sec}}{1\text{ min}}*\frac{60\text{ min}}{1\text{ hr}}*\frac{8\text{hr}}{1\text{ day}}*2\text{operator} = 1768\,\frac{\text{shirts}}{\text{day}}$$

The Existing Production Line Data

- No-of operator =19
- No-of machines= 18
- Total Smv = 450 seconds

From above given of data we will have the following productivity result

1. Theoretical output

$$Theoretical\ output = \frac{\text{No operators} * \text{working hours}}{\text{smv}}$$

$$= \frac{19\text{ operators} *\ 8\text{ hrs}*60\text{ mins} *60\ secs/day}{450\text{secs}}$$

$$= 1216\text{ shirts/ day}$$

2. Average actual output of the company = 850 shirts per day.
3. Line efficiency

$$E = \frac{\text{actual output}}{\text{theoretical output}} * 100$$

$$= \frac{850\text{shirts/day}}{1216\text{ shirts/day}} * 100\%$$

$$= 69.8\%$$

Method-1: Ranked Positional Weight Line Balancing Technique

1. List of tasks, task time and precedence

Table 6: List of tasks, task time, and precedence tasks

No	Tasks	Description of Tasks	Standard Task Time	Immediate predecessor
1	A	Brand label and attach on yoke	9.055	-
2	B	Back and yoke attach	10.48	A

3	C	Small placket attach with sleeve	16.821	-
4	D	Big placket attach with sleeve	14.016	-
5	E	Button hole making on front	15.35	B
6	F	Pocket attach on left front	12.4	E
7	G	Shoulder stitching	10.51	F
8	H	Collar attaching with body	13.78	G
9	I	Collar close	11.54	H
10	J	Sleeve attaching with body	15.14	C,D
11	K	Side seam stitching	32.584	J
12	L	In line checking	29.39	K
13	M	Bottom hemming	11.54	L
14	N	Cuff attaching	18.28	J
15	O	Trimming of bottom of hem	13.213	N,M
16	P	Point buttonhole on cuff, band and placket	32.24	O
17	Q	Button setting	11.54	P
18	R	Thread trimming	12.03	Q
19	S	Quality check	29.95	R

2. Precedence Diagram

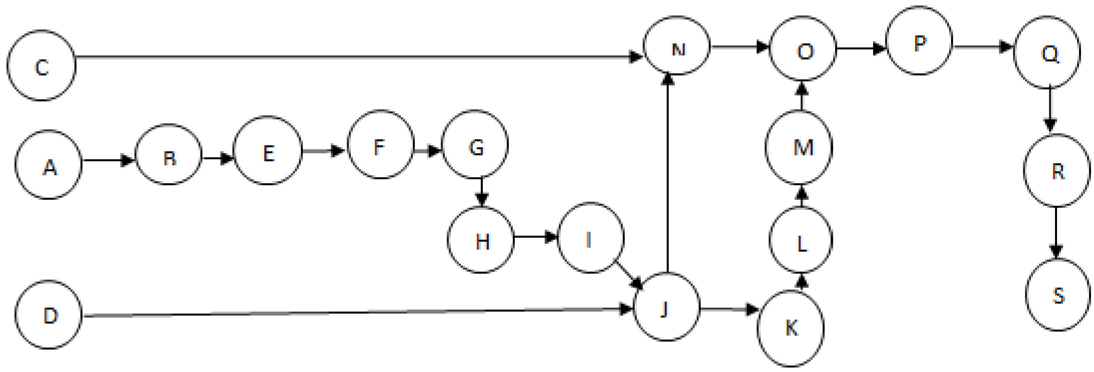

Figure 2: The precedence diagram

3. Cycle time

$$Ct = \frac{\text{production time per day}}{\text{average output per day}}$$

$$= \frac{8\text{hrs/day} * 60\text{mins} * 60\text{secs}}{850\text{shirts/day}}$$

$$= \frac{28800\text{secs}}{850\text{shirts/day}}$$

$$= \mathbf{33.88} \text{ secs/day}$$

4. The RPW must be calculated for each element (tasks)

RPWs=29.95 RPW d=249.873

RPW r=41.98 RPW a=273.657

RPWq =53.52 RPW b=275.082

RPW p=85.76 RPW e=279.952

RPW o=311.76 RPW f=277.002

RPW m=323.3 RPW g=275.112

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RPW l=352.69 RPW h=278.382

RPW k=385.274 RPW i=276.142

RPW j =403.554 RPW n=117.253

RPW c= 134.074

5. List of element or tasks Ranked according to their Ranked position Weight (RPW)

No	Tasks	RPW (Decreasing Order)	Task Time	Precedence
1	A	J	15.14	C,D
2	B	K	32.584	J
3	C	L	29.39	K
4	D	M	11.54	L
5	E	O	13.213	N,M
6	F	E	15.35	B
7	G	H	13.78	G
8	H	F	12.4	E
9	I	I	11.54	H
10	J	G	10.51	F
11	K	B	10.48	A
12	L	A	9.055	-
13	M	D	14.016	-
14	N	C	16.821	-
15	O	N	18.28	J
16	P	P	32.24	O
17	Q	Q	11.54	P
18	R	R	12.03	Q
19	S	S	29.95	R
SUM			Smv=311sec	

6. Work task assigned to stations according to the Ranked Position weight values

Work stations	Work tasks	Task time	Station time (second)
1	J	15.14	15.14
2	K	32.584	32.584
3	L	29.39	29.39
4	J	15.14	28.353
	O	13.213	
5	E	15.35	29.13
	H	13.78	
6	F	12.4	23.94
	I	11.54	

7	G	10.51	30.045
	B	10.48	
	A	9.055	
8	D	14.016	30.837
	C	16.821	
9	N	18.28	18.28
10	P	32.24	32.24
11	Q	11.54	23.57
	R	12.03	
12	S	29.95	29.95
Na=12			

7. Line efficiency

$$E = \frac{\text{sum of task times (T)}}{\text{actual number of work stations (Na)}*cycle\ time\ (Ct)}$$

$$= \frac{311\text{sec}}{12 * 33.88sec} * 100\%$$

$$= 76.495\ \%$$

8. Balance delay

$$D = \frac{\text{actual number of station (Na)} * cycle\ time(Ct) - sum\ of\ task\ time\ (T)}{\text{actual number of work stations (Na)}*cycle\ time\ (Ct)}$$

$$= \frac{12 * 33.88\text{sec} - 311\text{ sec}}{12 * 33.88\ sec} * 100\%$$

$$= 23.5\ \%$$

4. Smoothness index

$$\text{SI}=\sqrt{\sum_{i=1}^{n}[\mathbf{Ct} - \sum(\mathbf{ti} * \mathbf{Xij})]^{2}}$$

=916.7

Method-2: **Largest Candidate Line Balancing Technique**

1. In general, the strategy is to use a rule assigning tasks that either have many followers or are at long duration because they effectively limit the balance achievable. In this case, we use the following as our primary rule. Prioritize tasks in order of the largest number of following tasks

Tasks	**Number Of Following Tasks**
A	15
B	14
E	13
F	12
G	11
H	10
D,I	9
J	8
K	7

C,L	6
M,N	5
O	4
P	3
Q	2
R	1
S	0

2. To assign the elements to the first station, start at the top of the task and so on. A feasible element is on which satisfies the precedence requirements. Thus, the sum of the task time of all elements at that station should not exceed the cycle time.

Work stations	**Work tasks**	**Task time(second)**	**Station time (second)**
1	A	9.055	19.535
	B	10.48	
2	E	15.35	27.75
	F	12.4	
3	G	10.51	24.29
	H	13.78	
4	D	14.016	25.556
	I	11.54	
5	J	15.14	15.14
6	K	32.584	32.584
7	L	29.39	29.39
8	C	16.821	28.361
	M	11.54	
10	N	18.28	31.493
	O	13.213	
11	P	32.24	32.24
12	Q	11.54	23.57
	R	12.03	
13	S	29.95	29.95
Na=13		**311 second**	

1. Line efficiency (E)

$$E = \frac{\text{sum of task times (T)}}{\text{actual number of work stations (Na)}*cycle\ time\ (Ct)}$$

$$= \frac{311\text{sec}}{13 * 33.88sec} * 100\%$$

$$= 70.61\ \%$$

2. Balance delay(D)

$$D = \frac{\text{actual number of station (Na)} * cycle\ time(Ct) - sum\ of\ task\ time\ (T)}{\text{actual number of work stations (Na)} * cycle\ time\ (Ct)}$$

$$= \frac{14 * 33.88\text{sec} - 311\text{ sec}}{14 * 33.88\ sec} * 100\% = 29.39\ \%$$

3. Smoothness index (SI)

$$SI = \sqrt{\sum_{i=1}^{n} [\mathbf{Ct} - \sum(\mathbf{ti} * \mathbf{Xij})]^2}$$

=958.388

Results found from the line balancing Techniques

Table 7: Result found from Line Balancing Techniques

Line balancing Techniques	**No. of work station**	**Task time(second)**	**Idle time**	**Line efficiency**
Ranked Positional Weight	12	311	23.5 %	76.495 %
Largest candidate	14	311	29.39 %	70.61 %

Therefore, from the above result, the best line balancing techniques is Ranked Positional Weight Techniques which is have 12 numbers of work stations and 76.495 % of line efficiency compared with largest candidate techniques.

Summary of the Existing and Improved Production Line

Table 8: Comparing of Existing and Improved

	Existing Production Line	Improved Production Line
Total operators	19	19
Line efficiency	69.8 %	76.495%
Number of work stations	18	12
Daily actual output	850 shirts per day	1768 shirts per day

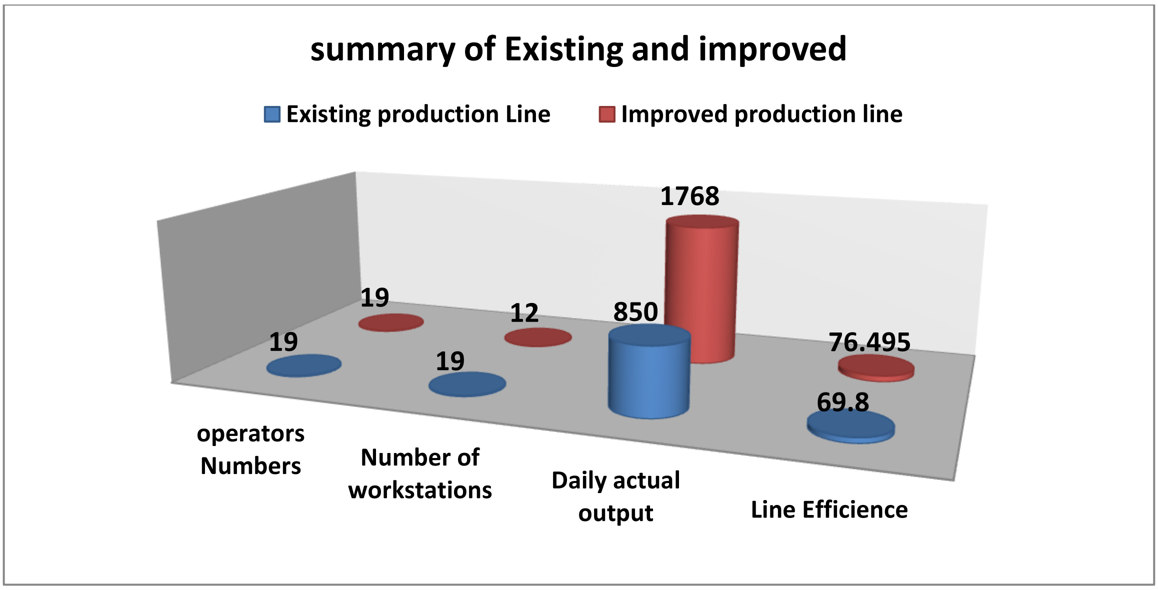

Figure 3: Summary of Existing and Improved

Comparison of Line Balancing Techniques Result from Different Articles

Table 9: Result Comparison of Line Balancing Techniques

Name of Authors	Title of articles	Line Balancing Techniques	Parameters Consideration in the Techniques	Result comparison
S.H.ERYU RUKF.KA LAOGLU, And M. BASKAK	Assembly Line Balancing in Clothing Company.	Ranked Positional Weight Techniques Probabilistic Techniques	The basic considerations parameters in these techniques according the research for both techniques are number of station, line efficiency, smoothness index and delay of time production line.	The researcher result shows that a Ranked position weight technique gives the maximum line efficiency, And minimum delay time and smoothness index compare with probabilistic technique.
Vrittika V Pachghare And R.S. Dalu	Assembly Line Balancing Methods	Largest candidate techniques Ranked Positional Weight (RPW) techniques Kilbridge and Wester Column (KWC) techniques	The basic considerations parameter in these techniques according to the researcher for both techniques are the Line Efficiency, Balance Delay, Number of Workstation ,Smoothness Index and Expected number of Production Rate in the production line.	The researcher decides that based on line efficiency and idle time the Ranked Positional Weight better than both techniques.
Mahmut Kayar,And Öykü Ceren Akyalçin	Applying Different Heuristic Assembly Line Balancing Methods in the Apparel Industry and their Comparison	Hoffman method Kilbridge & Western COMSOAL method Moddie & Young method Largest candidate rule Ranked Positional Weight	The basic considerations parameters in these techniques according to the researcher for the techniques are Line Efficiency and Balance Delay time.	The researcher decides that Hoffman and COMSOAL techniques are best in line efficiency and idle time. So that both techniques better than another techniques.

5. CONCLUSION

This paper worked on Lucy Garment Industry in Ethiopia. The aim of study is balancing production line by using line balancing techniques which are Ranked position weight and largest candidate method through work study method. As a result of analysis and articles review, it can be seen that the Ranked Positional Weight gives better results in the line efficiency and delay time minimization which compared to largest candidate technique. So that techniques minimize bottleneck operations and arranging the workload among work stations to increase line efficiency and minimize delay time. Before improvement, the production capacity of the company on an average for this specific model (regular size, fabric type polyester and men t-shirt), on this specific line (line-3) the line actual production capacity is 850 shirts per day. Therefore, from this analysis, the production capacity is increased from 850 shirts per day to 1768 shirts per day and line efficiency of the line is improved from 69.8 % to 76.495 % by applying the Ranked Position Weighting techniques which is better than largest candidate technique.

Finally concluded, that line balancing techniques are an effective technique for generating initial solutions for the garment industry to improve their productivities and efficiency.

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