Hawassa University Journals

Volume II
Pages: 146-161
Article Number: 931-Article Text-3474-1-6-20221224

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

Sewing Line Efficiency Improvement Using Line Balancing Methods for Case of JP Garment

Awraris Alemayehu[1], Fentahun Moges Kasie[1*], Sahle Mekta[1]

[1] *Industrial Engineering, Hawassa Institute of Technology, Assoc. Professor, Hawassa University, Hawassa, Ethiopia*

[*] *Corresponding author e-mail:* fentahunm@hu.edu.et

Abstract: Line balancing in the garment industry is one of the responsibilities of industrial engineers to improve the efficiency of sewing lines by leveling the output of every operation. In JP Garment Plc, the line efficiency of the long shirt sewing line is below the planned. One of the reasons was unbalanced workload distribution. This study focused on balancing the sewing line through different line-balancing techniques. To perform line balancing analysis primarily the researcher collects the operation breakdown and standard time of shirt production in JP garment. Next, a flow process chart and a precedence diagram were developed. The cycle time, which depends on the available time and the production target, is one of the key parameters in line balancing analysis and this time found as 33 seconds. Based on this cycle time, ranked positional weight and the largest candidate rule method of line balancing were used to improve the efficiency of the sewing line. The existing system has forty-one workstations with an efficiency of 67.6 %. By applying the ranked positional method, the number of workstations becomes thirty-four with 85.9% line efficiency and production enhanced to 902 shirts. Alternatively, the largest candidate rule method was applied and resulted in thirty-one workstations with an efficiency of 94.2%. Lastly, Kilbridge and Wester's method was applied and resulted in 97.35% efficiency and the number of workstations became thirty.

Keywords: Line Efficiency, Line balancing, Cycle time, Ranked Positional Weight, Largest Candidate Rule, Kilbridge and Wester's method

1. Introduction

The garment production system is one of the assembly line types of production system. An assembly line consists of a set of workstations where a set of operations are carried out to obtain the final product. In an assembly line, tasks are allocated to the workstations considering some restrictions including precedence constraints, cycle time, and the number of workstations, thus increasing its complexity. However, assembly lines are used extensively in mass production systems to produce high-quantity standardized products. For this reason, assembly line balancing becomes very crucial for the proper functioning of the assembly line system. However, assembly line balancing is a very complex phenomenon that has been named a nondeterministic polynomial (NP) hard problem or complex combinatorial problem. Even though research on assembly line balancing dates to more than a century, it is still of interest to many researchers. This is because the assembly line balancing problem (ALBP) is directly related to production efficiency (Bongomin, 2020).

The major stumbling block of the Ethiopian garment industry for global competitiveness is low productivity performance (Kitaw, 2010). The most commonly applied line-balancing techniques in the apparel industry include heuristics, metaheuristics, simulation, and hybrid approaches. The heuristic approach is based on logic (simple priority rules) and common sense rather than on mathematical proof and can generate one or a few feasible solutions. The most commonly used heuristic line-balancing method in the apparel industry is ranked positional weight, largest candidate rule, and Kilbridge and Wester's method (Kharuddin, 2020).

Ethiopia has a long history in garment and textile companies starting from 1939. Even though the country has different good opportunities for low labor cost, and low energy cost as compared with other countries, but efficiency level of the sector is still lower. In JP Garment Plc. the planned production output of the shirt and the actual production output of the shirt sewing line are not similar (the actual production output is less than the targeted one). Based on the daily production report of the company, the actual line efficiency of the shirt sewing line is around 67.6 percent on average. As compared to planned production per shift 85% percent on average. Also, the Planned Production of 875 long-sleeve shirts per shift but the actual production per line is 710 long-sleeve shirts this occurred due to a delay within different workstations. This delay occurred from an unbalanced assembly line arrangement and the problem can be reduced by balancing the sewing line. As a result, the objective of this study is to balance the sewing line through line-balancing techniques and to improve the line efficiency of the shirt production line. To the stated objective, the following specific objectives were attained in this paper.

- Determining the cycle time for the shirt manufacturing process since it is the key parameter in line balancing analysis.
- Developing the process flow chart and precedence diagram for the shirt manufacturing process.
- Performing line balancing analysis of shirt sewing line using Ranked positional weight, Largest Candidate Rule, and Kilbridge and Wester's methods.

The results of this study help the management of the JP Garment Factory and other similar factories to balance their sewing lines to improve sewing line efficiencies. Also, this research can educate the line-balancing experts in assembly lines to understand the importance of line-balancing methods. As an academic contribution, academicians and researchers can use the output of this study to teach their students about assembly line balancing, especially in the apparel production system

2. Literature Review

At present, line balancing techniques have received more attention than other line efficiency and process improvement techniques such as lean manufacturing (VSM), lean six sigma, six sigma, and hybrid approach (lean manufacturing and line balancing) (Islam, 2019). Line balancing techniques involve several constraints that must be put into consideration for example task assignment, task precedence, cycle time, and resource constraints. Several authors focused their studies on the comparison of the different techniques for heuristic line balancing (Bongomin, 2020).

2.1 Overview of Line Balancing

Line balancing means to allocate the work element equally in various workstations. Assembly line balancing is an important & challenging task for industrial engineers in today's mass production-oriented company. The key problem faced while balancing an assembly or operation line is how to assign a set of tasks to a specific workstation so that a precedence relationship is developed and performance is optimized (Ahmed, 2020)The production line is usually balanced for gaining a better that ultimately increases the line efficiency. A balanced process is one where cycle time in each stage is approximately equal. The revised layout is essential for any garment manufacturing company to assess its effectiveness (Kitaw, 2010).

The unequal workload in the workstation of an assembly line in a garment factory will lead to a higher increase in both work–in–progress (WIP) and waiting time. Thus, both production cycle time and cost are increased. So, industrial engineers are more concerned with the balance of the lines by appropriately assigning the tasks to workstations as equally as possible. One of the main challenges concerning the development of an assembly line invention only trial and error were used to balance the line. However this was costly time time-consuming and that is why the production manager needed to develop a new system (Jaganathan, 2014).

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 is optimal in some sense. Ever since Henry Ford's introduction of assembly lines, line balancing has been an optimization of production line problems to increase efficiency. The main objective of line balancing is to distribute the task evenly over the workstation so that the idle time of man or machine can be minimized. Line balancing aims for grouping the facilities or workers in an efficient pattern to; obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes (Adeppa, 2015). Balancing refers to the procedures of adjusting the operation times at work centers to conform as much as possible to the required CT (cycle time). Required cycle time is the production target of a process or operation that is determined by the demand for the item being produced process or operation that is determined by the demand for the item being produced. A balanced process is one where the actual cycle times at every stage are equal. Actual cycle time represents the actual production capability of a process or operation (Kitaw, 2010).

2.2 Methods of Line Balancing

Line balancing is an effective tool to improve the throughput of assembly lines while reducing non-value-added activities' cycle time. The goal of line-balancing techniques in any kind industries including garment industries is to minimize idle time as much as possible (Jaggi, 2015). For industrial sectors, balancing assembly lines is a crucial task to increase productivity by reducing cycle time or the number of workstations. The balancing issues control how tasks are assigned to workstations to accomplish the intended objectives. Assigning tasks to workstations so that each total duration of assigned tasks to each workstation has an equal line cycle time is a common practice in assembly line balance (Roshani, 2017). The largest candidate rule, Kilbride & waster (column), ranked positional weights (RPW) are heuristic methods commonly used in assembly line balancing to arrange and distribute the work elements according to their task time in different workstations in the system (Paprocka, 2022).

The ranked positional Weight Method (RPW) was introduced by Helgeson and Birnie in 1961, which is a value to be computed for each element in the system. In this method, a Ranked Positional Weight considers both the Tek value and its position in the precedence diagram. In particular, RPWk is calculated by summing T_{ek} and all other times for elements that follow T_{ek} in the arrow chain of the precedence diagram. Tek is the time to perform work element k, minute and hence these values of Tek are additives The RPW method has been recognized as one of the techniques of the line balancing process in the manufacturing industry, which means the process of scheduling assembly activities in a production line aims to maximize velocity and efficiency at each work station and line balancing so that all work stations operate at the same velocity. In the Ranked Positional Weight method, one can assign cycle time and then calculate the workstations required for the production line or vice versa (Siregar, 2020).

Chavare(2015) applies the ranked positional weight method to reduce bottlenecking of the assemblies of the engine. In his study number of workstations have been decided and a proper layout has been proposed based on the RPW method. Before implementing the RPW method production rate was 210 engines per month. After implementing the RPW method, the production rate was increased by 25% with 300 engines per month.

Kilbridge and Wester's (column) method is a heuristic procedure that selects work elements for assignment to stations according to their positions in the precedence diagram. These methods are known for their reliability in overcoming difficulties such as encountered in the Largest Candidates Rule method where an element could be selected concerning a high T_e value but irrespective of its position in the precedence diagram. However, in the column method, the elements are arranged into columns (Groover, 2016). A study conducted by Manaye (2019) shows that the production capacity has increased from 850 shirts per day to 1768 shirts 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 the largest candidate technique.

Panchal, (2020) uses both the Ranked Position Weighted and Kilbridge and Wester Method at the Radiator assembly Plant and improves the productivity of the plant. Using Kilbridge and Wester's line balancing method production rate has increased from 500 units/shift to 590 units/shift. A higher value of line efficiency and lower value of smoothness-index suggests that the line is smooth also achieved.

Jaggi, (2015) used three manual line balancing methods (Largest Candidate Rule, Kilbridge and Westesr's Method, and Ranked Positional Weight) and four generated alternatives were used to balance the assembly line of a car manufacturing company to improve the efficiency of its situation. Results show that productivity increased about three times higher than the assembly line efficiency before the study.

Different related kinds of literature were reviewed to get insights and analyze the gaps in their productivity improvement approaches; mainly specific to assembly line balancing. This indicates that assembly line balancing is a crucial method to improve the productivity and line efficiency of assembly lines. However, it was not sufficiently studied in the Ethiopian garment and apparel industries. This study aims to bridge this gap by applying the three popular line-balancing methods in the JP Garment Factory at Hawassa Industrial Park.

3. Research Methodology

To complete this research successfully, a detailed literature survey, data collection using different techniques, and data analysis using line balancing tools were conducted. Mostly review of books and journal articles was performed to understand concepts related to line balancing, productivity, and methods of line balancing for analysis methods. In the data collection process, a secondary data collection mechanism was utilized. The collected data was analyzed using the formulas that are related to line balancing and standard time. During the analysis of data, Microsoft Office Excel is used to document the raw data and it is used to present the result of the data through different tables. Microsoft Visio was also utilized to draw the process flow chart and precedence diagram. Ranked positional weighted, largest candidate rule method, and Kilbridge and Wester's (column) method of line balancing was used to improve the productivity and efficiency of the production line. The following formulas were also used;

$$\text{Line efficiency} = \frac{\text{Output} * \text{SMV}}{\text{number of operators} * \text{available working minutes}}$$

Balance Delay = 1-Line Efficiency

Cycle time was calculated as;

$$\text{Cycle time} = \frac{\text{Available production time per shift}}{\text{target production output}}$$

4. Data Analysis and Discussion

JP Garment Company (JP) was established by the Chinese government by its mother company China Hong Kong in Ethiopia in December 2019 in the Hawassa Industrial Park area of 5500 square meters. The company is located in Hawassa, which is approximately 270 Km South of Addis Ababa, which has great potential in workforce and infrastructure, and express road contact from the capital city and Djibouti port is available.

4.1 Process Flow of Shirt Sewing Line

The shirt production facility is composed of cutting sections, small parts preparation, front parts, and back parts preparation, assembly section and finally finishing section for final inspection and packing.

Table 1. Long sleeve sewing processes and time (Source: JP garment's OB)

Process code	Operation name	Process time(sec.)	Process code	Operation name	Process time(sec.)
A01	Pocket iron	30	B06	Collar Attach	32
A02	Sleeve placket iron	21	B07	Collar close	30

A03	Pocket outline	6	B08	Cuff attach	31
A04	Sleeve binding	33	B09	cuff outline	28
A05	Top front plkt. Stitch	13	B10	Bottom hem	32
A06	Under front plkt. Stitch	23	C12	Cuff iron	23
A08	Back yoke pleat & attach	30	C13	Sleeve trimming	20
A09	Back yoke outline	11.5	C15	Pairing front	19.3
A10	Sleeve placket outline	19.6	C16	Shoulder trim	17
A11	Collar stand iron	19	C17	Sleeve placket marking	12
A12	Collar stand outline	7	C21	Pocket attach	16
A13	Collar stitch outline	22	C22	Sleeve Attach	19
A14	Collar stitch template	31	C23	Sleeve placket buttonhole	5
A15	Collar iron	22	C24	Sleeve placket bartack	5
A16	Collar trim and mark	26	C25	Front top placket buttonhole	26
A17	Main & size labels attach	27.2	C31	Collar stitch	14
B01	Shoulder attach	31	C32	Collar trim and mark	8
B02	Shoulder outline	23.8	C33	Collar overturning	9
B03	Sleeve attach	32	C34	Cuff stitch	19
B04	Armhole outline	32	C35	Cuff overturning	8
B05	Side seam stitch	33		.	

Existing production line data

- Based on this data, the total process time for a long-sleeved shirt is 963.8 seconds (16 minutes).
- The number of workstations = 41
- Number of operators assigned = 35
- Production target per line per shift = 875 shirts (@ 85% efficiency)
- Average actual production per shift per line = 710 shirts (67.6%-line efficiency).

Existing line efficiency = $\frac{Output*SMV}{number\ of\ operators*available\ working\ minutes} = \frac{710*16min}{35*480} * 100\% = 67.6\%$

From the above information, we can understand that actual production is less than the planned production. Therefore, it needs some interventions to enhance the productivity of the line. One of the popular industrial engineering techniques used to enhance the productivity of sewing lines is line balancing analysis. To perform line balancing analysis first, we need to understand the process flow of the garment production system.

Option One

I. Line Balancing Analysis using Ranked Positional Weight (RPW) Method

The Ranked Positional Weight (RPW) solution is one of the more efficient ways of assigning job elements to stations than the other methods. In the RPW method, you can set the cycle time and then calculate the workstations required for the production line or vice versa. this matter cannot be performed in any other line balance method. The steps of the Ranked Positional Weight method are as follows. Step 1:

Table 2. List operations, task times, and predecessor operations as shown below

Process code	Task time(sec.)	Predecessor	Process code	Task time(sec.)	Predecessor
A01	30	-	B06	32	B05, A16
A02	21	A04	B07	30	B06
A03	6	A01	B08	31	B07, C12
A04	33	C17	B09	28	B08
A05	13	C21	B10	32	B09
A06	23	A05	C12	23	C35
A08	30	-	C13	20	-
A09	11.5	A08	C15	19.3	A03
A10	19.6	A02	C16	17	A17, C25
A11	19	C33	C17	12	C13
A12	7	A11	C21	16	C15
A13	22	A12	C22	19	A10
A14	31	A13	C23	5	C22
A15	22	A14	C24	5	C23
A16	26	A15	C25	26	A06
A17	27.2	A09	C31	14	-
B01	31	C16, A17	C32	8	C31
B02	23.8	B01	C33	9	C32
B03	32	C24, B02	C34	19	-
B04	32	B03	C35	8	C34
B05	33	B04			

Step2: Create a precedence diagram

In line balancing analysis, preparing the precedence diagram is one of the main activities and to create the precedence diagram first we need to draw the process flow chart of the shirt manufacturing system.

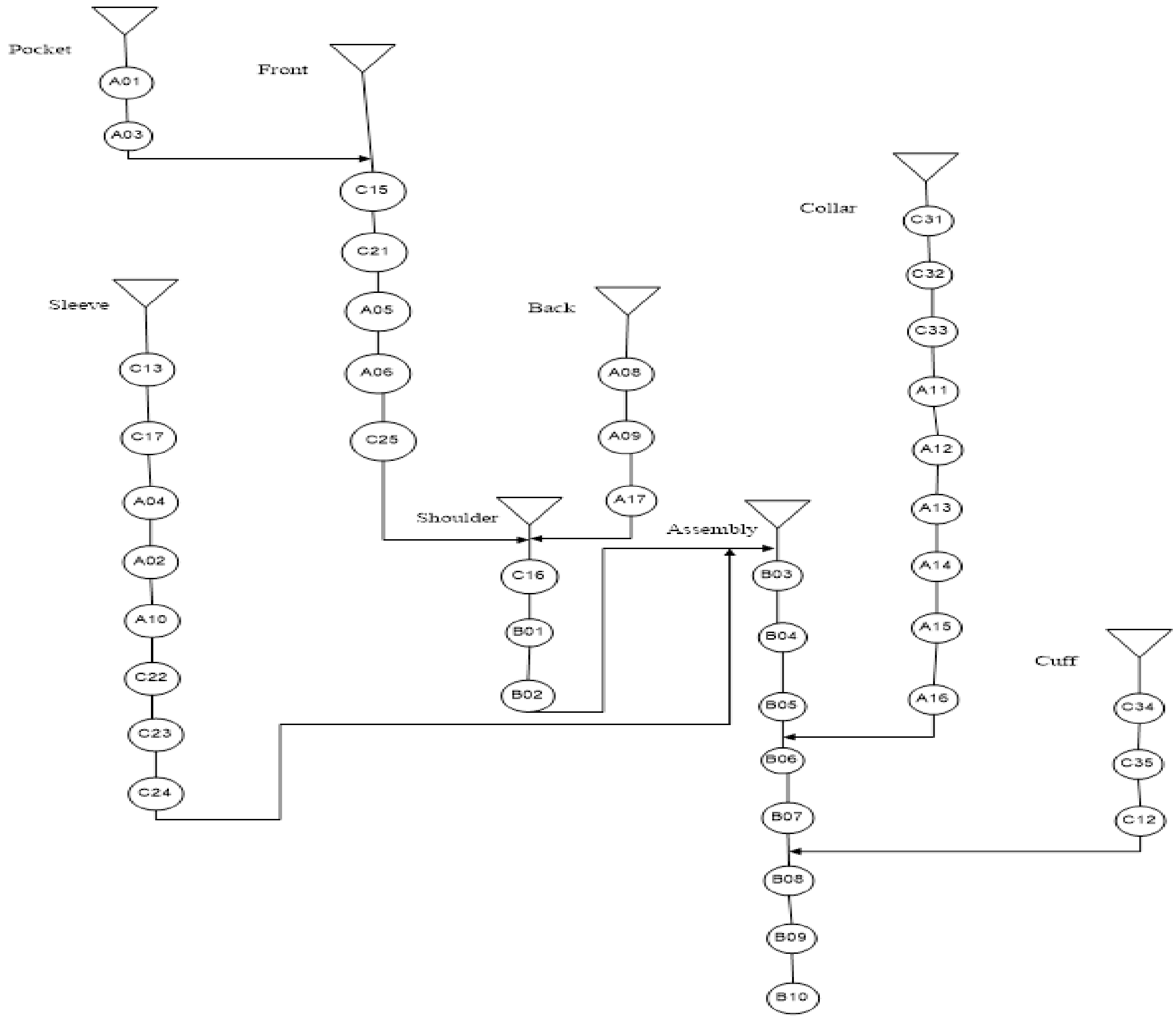

Figure 1. Process flow chart of shirt-making

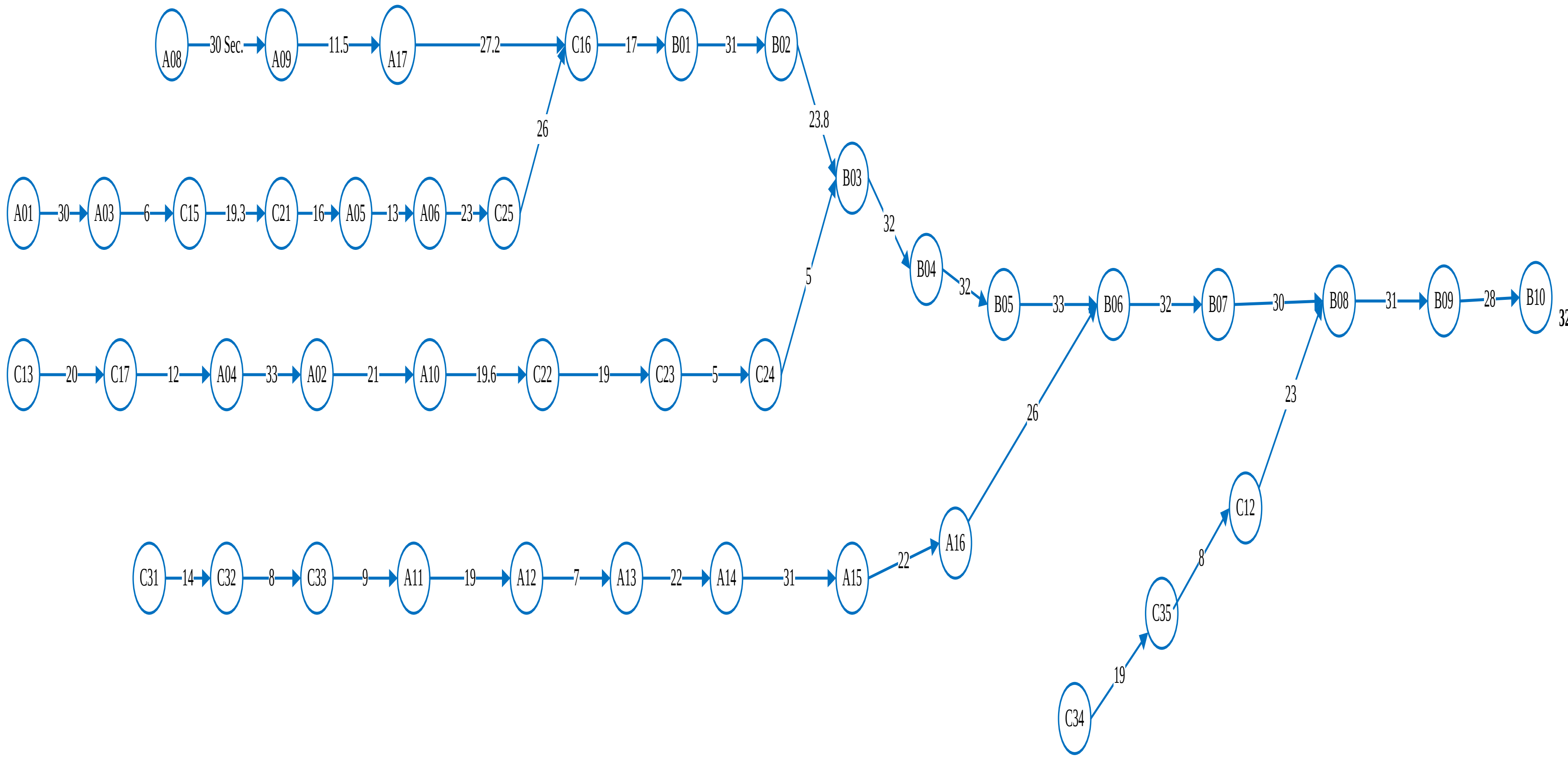

Figure 2. Precedence diagram of shirt making in JP garment

Step 3: Calculate the cycle time

$$Cycle\ time = \frac{Available\ production\ time\ per\ shift}{target\ production\ output} = \frac{8hrs*60min*60sec}{875shirts} = 33\ seconds$$

Step 4: Calculate the position weight of each operation which is calculated based on the total time of the operation and the operations that follow it and summarized in the table below.

Table 3. Calculation of positional weight for each operation

Process code	Task time(sec.)	Predecessor	Position Weight	Process code	Task time(sec.)	Predecessor	Position Weight
A01	30	_	455.1	B05	33	B04	186
A02	21	A04	319.6	B06	32	B05, A16	153
A03	6	A01	425.1	B07	30	B06	121
A04	33	C17	352.6	B08	31	B07, C12	91
A05	13	C21	383.8	B09	28	B08	60
A06	23	A05	370.8	B10	32	B09	32
A08	30	_	390.5	C12	23	C35	114
A09	11.5	A08	360.5	C13	20	_	384.6
A10	19.6	A02	298.6	C15	19.3	A03	419.1
A11	19	C33	280	C16	17	A17, C25	321.8
A12	7	A11	261	C17	12	C13	364.6
A13	22	A12	254	C21	16	C15	399.8
A14	31	A13	232	C22	19	A10	279
A15	22	A14	201	C23	5	C22	260
A16	26	A15	179	C24	5	C23	255
A17	27.2	A09	349	C25	26	A06	347.8
B01	31	C16, A17	304.8	C31	14	_	311
B02	23.8	B01	273.8	C32	8	C31	297
B03	32	C24, B02	250	C33	9	C32	289
B04	32	B03	218	C34	19	_	141
				C35	8	C34	122

Step 5: Rank the operations from the largest to the smallest operating weight and then Assign the workstations by considering the eligibility criteria

:

The task with a higher weight should be assigned first.

- Predecessor tasks should be assigned
- Considering the cycle time i.e., not to exceed the cycle time in a particular workstation.

Table 4. Ranking of Operations based on their weight

Rank	Process Code	Position Weight	Rank	Process Code	Position Weight
1	A01	455.1	21	A11	280
2	A03	425.1	22	C22	279
3	C15	419.1	23	B02	273.8
4	C21	399.8	24	A12	261
5	A08	390.5	25	C23	260
6	C13	384.6	26	C24	255
7	A05	383.8	27	A13	254
8	A06	370.8	28	B03	250
9	C17	364.6	29	A14	232
10	A09	360.5	30	B04	218
11	A04	352.6	31	A15	201
12	A17	349	32	B05	186
13	C25	347.8	33	A16	179
14	C16	321.8	34	B06	153
15	A02	319.6	35	C34	141
16	C31	311	36	C35	122
17	B01	304.8	37	B07	121
18	A10	298.6	38	C12	114
19	C32	297	39	B08	91
20	C33	289	40	B09	60
			41	B10	32

Here, we are getting thirty-four (34) workstations and the line efficiency becomes:

$$Line\ efficiency = \frac{Sum\ of\ processing\ time}{number\ of\ workstations * cycle\ time} * 100\% = \frac{963.8}{34*33} * 100\% = 85.9\%$$

Balance Delay = 1-Line Efficiency = 1-0.859 = 14.1%

Or, the line can produce 902 shirts per line per shift.

$$Line\ efficiency = \frac{Output * SMV}{number\ of\ operators * available\ working\ minutes} = \frac{Y16}{35*480}$$

$0.859 = \frac{16Y}{35*480}$ then solving for Y gives an output of 902 shirts per line per shift

This efficiency is greater than that of the actual line efficiency which is 67.6%.

Therefore, the ranked positional weighted method of line balancing helps us to improve the productivity of the shirt sewing line.

The workstation allocation is summarized in the next table.

Table 5. Workstation allocation result of Ranked Positional Weight method

Workstation #	Element	Task time	Workstation time	Idle time
1	A01	30	30	3
2	A03	6		
	C15	19.3	25.3	7.7
3	C21	16	16	17
4	A08	30	30	3
5	C13	20	20	13
6	A05	13	13	20
7	A06	23	23	10
8	C17	12	23.5	
	A09	11.5		9.5
9	A04	33	33	0
10	A17	27.2	27.2	5.8
11	C25	26	26	7
12	C16	17	17	16
13	A02	21	21	12
14	C31	14	14	19
15	B01	31	31	2
16	A10	19.6	27.6	
	C32	8		5.4
17	C33	9		
	A11	19	28	5
18	C22	19	19	14
19	B02	23.8	23.8	9.2
20	A12	7	17	
	C23	5		
	C24	5		16
21	A13	22	22	11
22	B03	32	32	1
23	A14	31	31	2
24	B04	32	32	1
25	A15	22	22	11
26	B05	33	33	0
27	A16	26	26	7
28	B06	32	32	1
29	C34	19	27	
	C35	8		6
30	B07	30	30	3
31	C12	23	23	10
32	B08	31	31	2
33	B09	28	28	5

34	B10	32	32	1

Option Two

II. Line Balancing Analysis using the Largest Candidate Rule (LCR) Method

In the largest candidate rule method, the work elements are arranged in descending order according to their work element time values. The following steps are involved to use the largest candidate rule method of line balancing.

Step 1: List all elements in descending order of Task element Te value, largest Te at the top of the list.

Table 6. Ordering operations based on task element

Process code	Task time Te (sec.)	Predecessor
B05	33	B04
A04	33	C17
B03	32	C24, B02
B04	32	B03
B06	32	B05, A16
B10	32	B09
B08	31	B07, C12
A14	31	A13
B01	31	C16, A17
B07	30	B06
A08	30	-_
A01	30	-_
B09	28	B08
A17	27.2	A09
A16	26	A15
C25	26	A06
B02	23.8	B01
A06	23	A05
C12	23	C35
A13	22	A12
A15	22	A14
A02	21	A04
C13	20	-_
A10	19.6	A02
C15	19.3	A03
A11	19	C33
C22	19	A10
C34	19	_-
C16	17	A17, C25
C21	16	C15
C31	14	_-
A05	13	C21
C17	12	C13
A09	11.5	A08
C33	9	C32
C32	8	C31
C35	8	C34
A12	7	A11

A03	6	A01
C23	5	C22
C24	5	C23

Step 2: To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element satisfies the precedence requirements and does not cause the sum of the Tej value at the station to exceed the cycle time Tc = 33 seconds per unit.

From the above table, we can observe that operations “B05” and “A04” have the largest Te, but due to precedence issues, these operations are not eligible to be assigned in the first workstation. Therefore, we need to search for another operation that fulfills both the precedence criteria and cycle time. Operation "A01" should be assigned at workstation one because it satisfies both the precedence requirements and cycle time requirements.

Step 3: Repeat step 2 until all of the operations are should be assigned in a particular workstation. The next table shows the results.

Table 7. Workstation allocation result of Largest Candidate Rule method

Workstation No.	Process	Task time	Station time Te	**Workstation No.**	Process	Task time Te	Station time
1	A01	30	30	**15**	A15	22	22
2	A08	30	30	**16**	A16	26	26
	C13	20			C22	19	
3	C17	12	32	**17**	C23	5	
4	A04	33	33		C24	5	29
	A02	21		**18**	C21	16	
5	A09	11.5	32.5		A05	13	29
6	A17	27.2	27.2	**19**	A06	23	23
	C34	19		**20**	C25	26	26
7	C31	14	33	**21**	C16	17	17
8	C35	8		**22**	B01	31	31
	C12	23	31	**23**	B02	23.8	23.8
	C32	8		**24**	B03	32	32
9	C33	9		**25**	B04	32	32
	A03	6	23	**26**	B05	33	33
10	A10	19.6	19.6	**27**	B06	32	32
11	C15	19.3		**28**	B07	30	30
	A11	19		**29**	B08	31	31
12	A12	7	26	**30**	B09	28	28
13	A13	22	22	**31**	B10	32	32
14	A14	31	31				

Here, we are getting thirty-one (31) workstations and the line efficiency becomes:

Line efficiency = $\frac{Sum\ of\ processing\ time}{number\ of\ workstations * cycle\ time} * 100\% = \frac{963.8}{31*33} * 100\% = 94.2\%$

Balance Delay = 1-line efficiency = 1-0.942 = 5.8%

$$Line\ efficiency = \frac{Output*SMV}{number\ of\ operators*available\ working\ minutes} = \frac{Y16}{35*480}$$

$0.942 = \frac{16Y}{35*480}$ then solving for Y gives an output of 987 shirts per line per shift

This efficiency is greater than that of the actual line efficiency which is 67.6%.

Option Three

III. Kilbridge and Wester's column (KWC) Method

Kilbridge and Wester's (column) method is a heuristic procedure that selects work elements for assignment to stations according to their positions in the precedence diagram. These methods are known for their reliability in overcoming difficulties such as encountered in the Largest Candidates Rule method where an element could be selected concerning a high Te value but irrespective of its position in the precedence diagram.

Step 1: Prepare the Precedence diagram as shown in Figure

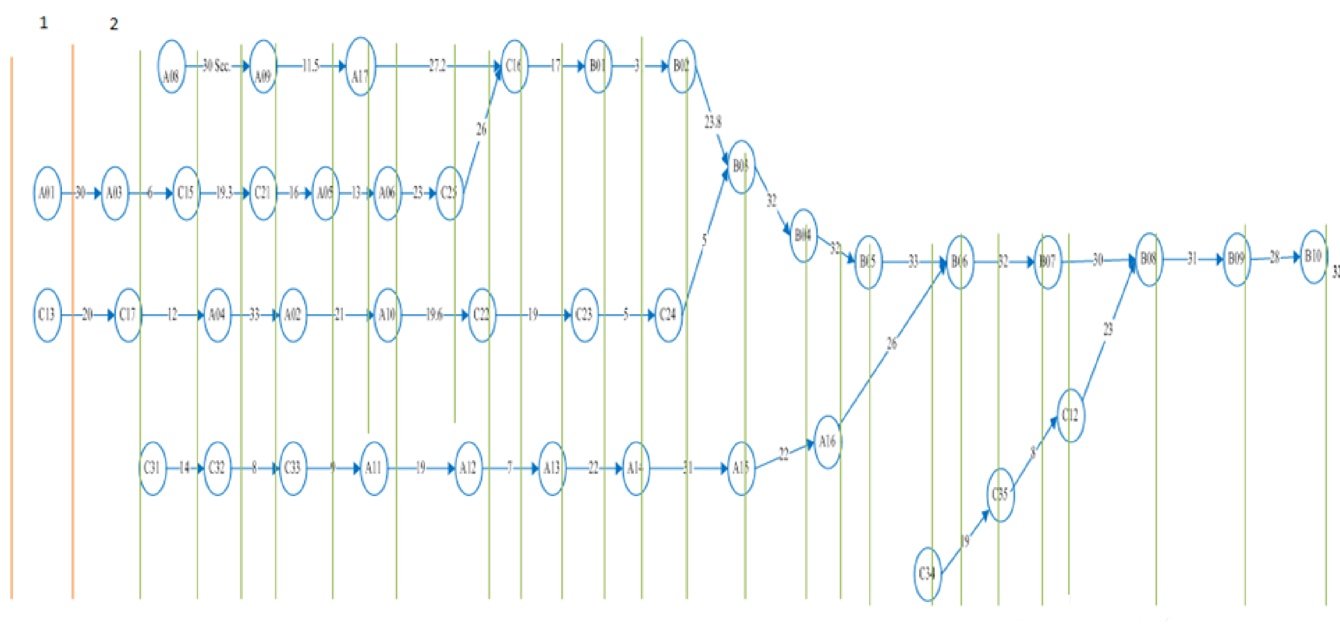

Figure 3. Precedence diagram column station sample of the shirt in JP garment

Step 2: As per the position of elements in the precedence diagram, organize them into columns and assign work elements to the station such that it does not exceed the cycle time as depicted in the table.

Here, we are getting thirty-one (30) workstations and the line efficiency becomes:

$$Line\ efficiency = \frac{Sum\ of\ processing\ time}{number\ of\ workstations*cycle\ time} * 100\% = \frac{963.8}{30*33} * 100\% = 97.35\%$$

This efficiency is greater than that of the actual line efficiency which is 67.6%

Balance Delay = 1-line efficiency = 1-0.9735 = 2.65%

Or, the line can produce 987 shirts per line per shift.

$$\text{Line efficiency} = \frac{Output*SMV}{number\ of\ operators*available\ working\ minutes} = \frac{Y16}{35*480}$$

$0.9735 = \frac{16Y}{35*480}$ then solving for Y gives an output of 1022 shirts per line per shift

Table 8. Summary and comparison of results

Metrics	Existing	Proposed			Remark
		Ranked Positional Weight Method	Largest Candidate Rule Method	Kilbridge Wester's Column Method	
Number of Workstations	41	34	31	30	***Reduced***
Output per shift	710	902	987	1022	***Improved***
Line Efficiency	67.6%	85.9%	94.2%	97.35 %	***Improved***
Balance Delay	32.4%	14.1%	5.8%	2.65%	***Reduced***

Therefore, from the above result, the largest candidate rule line balancing technique gives us better improvements than that of the Ranked Positional Weight technique also Kilbridge and Wester's Column (KWC) Method gives better improvements than the largest candidate rule method.

5. Conclusion

This study aimed to balance the sewing line in the JP Garment of Hawassa Industrial Park. 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. Minimizing the balance delay or minimizing the number of workstations is one of the importance of line balancing techniques. Lower shift production output of the sewing line was identified as a challenge to the case company. From the daily production report, the current average output per shift per line is 710 long-sleeved shirts with an efficiency of 67.6 percent.

Process flow charts and precedence diagrams were developed using Microsoft Visio since these issues are the basic in-line balancing analysis. Cycle time was calculated based on the available effective production time and the demand. And the cycle time becomes 33 seconds per unit. This cycle time is the most important parameter for conducting line balancing analysis. First, line balancing was performed using the Ranked Positional Weight (RPW) method and it resulted in 34 workstations and a line efficiency of 85.9 percent to produce 902 long-sleeve shirts per shift. Secondly, line balancing was performed using the Largest Candidate Rule (LCR) method and it resulted in 31 workstations and a line efficiency of 94.2 percent with this line efficiency an output of 987 long sleeve shirts per line per shift will be achieved. Lastly, Kilbridge Wester's Column method of line balancing was analyzed and resulted in a line efficiency of 97.3 with 30 workstations to produce 1,022 long-sleeve shirts per shift.

Therefore, these scientific line balancing methods have practical contribution to improve the efficiency of an assembly line (sewing line for our case).

References

Adeppa, A. (2015). A Study on Basics of Assembly Line Balancing. *International Journal on Emerging Technologies, 6*(2), 294.

Ahmed, T. a. (2020). Application of line balancing heuristics for achieving an effective layout: a case study. *International journal of research in industrial engineering, 9*(2), 114-129.

Bongomin, O. a. (2020). A complex garment assembly line balancing using simulation-based optimization. *Engineering Reports, 2*(11), e12258.

Chavare, K. B. (2015). Application of Ranked Position Weighted (RPW) Method for Assembly Line Balancing. *International Journal for Research in Applied Science & Engineering Technology (IJRASET), 3*(6), 254-262.

Groover, M. P. (2016). Automation, production systems, and computer-integrated manufacturing. *Pearson Education India*.

Islam, M. S. (2019). Production efficiency improvement by using tecnomatix simulation software and RPWM line balancing technique: A case study. *American Journal of Industrial and Business Management, 9*(4), 809.

Jaganathan, V. (2014). Line balancing using largest candidate rule algorithm in a garment industry: a case study. *International journal of lean thinking, 5*(1), 25-35.

Jaggi, A. a. (2015). Application of line balancing to minimize the Idle time of workstations in the production line with special reference to the automobile industry. *IJEASR, 4*(7), 8-12.

Kharuddin, M. H. (2020). Line balancing using heuristic procedure and simulation of the assembly line. *Indonesian J Elect Eng Comput Sci, 17*(2), 774-782.

Kitaw, D. a. (2010). Assembly line balancing using simulation technique in a garment manufacturing firm. *Zede journal, 27*, 69-80.

Manaye, M. (2019). Line balancing techniques for productivity improvement. *International Journal of Mechanical and Industrial Technology, 7*(1), 89-104.

Panchal, P. B. (2020). Application of Ranked Position Weighted and Kilbridge and Wester Method at Radiator Assembly Plant-A Case Study. *Int. J. Res. Appl. Sci. Eng. Technol, 8*(5), 2717-2724.

Paprocka, I. a. (2022). A predictive approach for disassembly line balancing problems. *Sensors, 22*(10), 3920.

Roshani, A. a. (2017). Simulated annealing algorithms for the multi-manned assembly line balancing problem: minimizing cycle time. *International Journal of Production Research, 55*(10), 2731-2751.

Siregar, I. (2020). Application of ranked positional weights method in spring production line balancing. *IOP Conference Series: Materials Science and Engineering*.