Available Online : https://proceeding.researchsynergypress.com/index.php/cset/index
RSF Conference Series: Engineering and Technology
ISSN 2809-6843 (Online) | 2809-6878 (Print)
Volume 2 Number 1 (2022): 23-36

Application of Ranked Position Weight and Region Approach Method in Overcoming Bottlenecks in Garment Industry

Hsueh-Lin Chang[1], Riana Magdalena Silitonga[2], Yennie Zelita[3], Muna Adilah[4], Yung-Tsan Jou[5]

[1,2,5] Department of Industrial and System Engineering, Chung-Yuan Christian University, Taiwan
[2,3,4] Department of Industrial Engineering, Atma Jaya Catholic University of Indonesia, Indonesia

Abstract

PT. Batik Delapan Satu is a manufacturing company specializing in the garment field. There is a bottleneck line at the production that can cause production to be hampered. This bottleneck line occurs at the trimming workstation, so imbalanced work flow. Then, we use Line balancing with the Ranked Positional Weight method and the Region Approach method to solve this bottleneck line problem. Using the Ranked Positional Weight method and the Region Approach method will produce line efficiency, balance delay, idle time, and smoothness index. Using the Ranked Positional Weight method and the Region Approach method will increase efficiency line from the condition of the company start 52.02% up to 73.82%. Besides that, it can reduce five-station work, which was seven-station work before, and reduce the level of idle time in the company, they used to take 1057.83 seconds, but now they only take 427.92 seconds.

Keywords: *Line Balancing; Bottleneck; Line Efficiency; Balance Delay; Idle Time*

INTRODUCTION

Line Balancing (LB) is very important for companies in the mass production type, according to (Yulianti, 2018) with the creation of trajectory balance, an optimal production capacity and high level of work efficiency will be achieved. Imbalance and inefficiency in the line can cause the operation process to be hampered so that there is a queue of semi-finished goods (bottleneck).

PT. Batik Delapan Satu faces a problem regarding the inbalance of the production line of one operation process with one another and resulting in a bottleneck. Imbalance and inefficiency in the line can cause the operation process to be hampered so that there is a queue of semi-finished goods (bottleneck) (Juwita, 2004).

Figure 1 shows the production process at PT. Batik Eight One. This company has 7 stages of the production process, starting from cutting, numbering, sewing, trimming, ironing, quality control, and ending with packaging. In the entire production process, the trimming stage only has one work element with a level of work that takes a very long time. This process is what causes the bottle neck (product buildup). This causes delays in the process at a later stage, especially at the packaging station as the last production station.

The bottleneck problem that occurs in this company causes an imbalance in the production line. According to (Trenggonowati & Febriana, 2019), this bottleneck problem is overcome by using the Line Balancing (LB) approach, so that work efficiency can be achieved properly. Meanwhile, according to Fudianto & Munir (2017), Line Balancing itself aims to reduce production queues and minimize waiting time in the production flow. Therefore, the LB approach can be used to overcome bottlenecks

Corresponding author
samchang.kw@gmail.com; riana.magdalena@atmajaya.ac.id; yenniezelita@gmail.com; ytjou@cycu.edu.tw

DOI : 10.31098/cset.v2i1.507

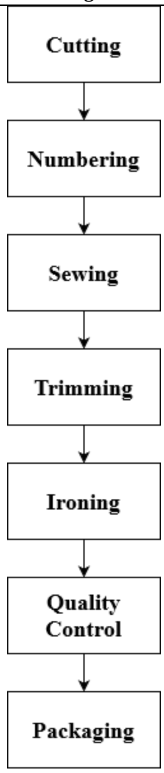

Figure 1. Production Process Flow of PT. Batik Delapan Satu

In this study, the LB approach can be carried out by applying the Ranked Positional Weight method and the Region Approach method. According to (Ekoanindiyo & Helmy, 2017) the Ranked Positional Weight method can solve production line imbalance problems and find solutions quickly. Meanwhile, according to (Basuki, MZ, Aprilyanti, & Junaidi, 2019) the design of the production line with the Region Approach method can minimize the slack time that workers have to carry out activities.

The problem occurred PT. Batik Delapan Satu is the accumulation of goods after they are finished at one work station, resulting in a bottleneck on the production line. Thus, this research was conducted to increase the efficiency of the production line in the workstation at PT. Batik Delapan Satu, minimizing bottlenecks at PT. Batik Delapan Satu by reducing the number of workstations using the Ranked Positional Weight method and the Region Approach method and reducing the idle time in the PT. Batik Delapan Satu. There are two limitations when working on this research: the measurement of production time only on the dominant type of clothing produced by PT. Batik Delapan Satu and the data used in the study are based on measurements made on each work element in the workstation.

LITERATURE REVIEW

Line balancing

Assembly line balancing or line balancing is the problem to determine the various task to the workstations by optimizing one or more objectives without involving any risk into the Line (Mengistu, 2019). The objective in the line balancing is to minimize the imbalance load between the machine and the worker by regulating the maximum output by using the minimum number of workstations (Plenert, 1997).

Line balancing has been a trending field of research in production system over the past decades due to its relevancies to the different industries such as garment, footwear, and electronics company (Chen et al., 2012). Commonly, the Line Balancing (LB) technique is used by many companies to improve the productivity in the Line by decreasing the number of labor, reducing the ideal time, and producing two products at the same time to optimize the consuming time (Firake & Inamdar, 2014).

There are some criteria that must be considered before applying line balancing approach. These are described as follow:

1) Time Study
The data that has been obtained from the company will be processed using the Time Study method, the first step taken in this method is to test the uniformity of the data that has been taken, after testing the data uniformity test and the data is uniform. Then the data will be continued with the data adequacy test, determining the normal time and time by setting the adjustment factor and allowance factor for each work station.

a) Data uniformity test
Data uniformity test is used to minimize the existing variance by removing extreme data, here is the formula for testing uniformity.

$$\overline{X} = \frac{\sum xi}{N} \qquad (1)$$

Information:
$\overline{X}$ = Average operating time
xi = Total operating time
N = Number of measurements taken

To decide the normal distribution of data, Kolmogotov Smirnov test was utilized. If the value of the data significance is bigger than the error level (5%), then data is normal (Wignjosoebroto, 2008). To conduct the normal test, Upper Control Limit (UCL) and Lower Control Limit (LCL) test is determined by using the below formula (Apriyono & Taman, 2013):
Information:
σ = Standard deviation
xi = Data operation time to i

$$UCL = \bar{x} + (\text{k } x\ \sigma) \qquad (2)$$
$$LCL = \bar{x} - (\text{k } x\ \sigma) \qquad (3)$$

Where: The value of k = 1 if the confidence level is 68%, the value of k = 2 if the 95% confidence level and the value of k = 3 if the 99% confidence level.

b) Data adequacy test
After the UCL and LCL are already defined, researchers need to test adequacy observation data. This data trial was carried out to find out the data that had been taken was sufficient. The data that has been taken is known enough when N' ≤ N is not necessary to retrieve the data again, and if N' ≥ N then the data is not sufficient (Wignjosoebroto, 2008). Here is the formula for performing the uniformity test:

$$N' = \frac{\frac{k}{s}\sqrt{N\ \Sigma xi^2 - (\Sigma xi)^2}}{\Sigma \text{xi}} \qquad (4)$$

Information:
N' = Number of measurements required
N = Number of measurements taken
k = Confidence level

In the measurement of work the collected data is time. The collected time data is used by stakeholders to find out the cycle time in completing a certain task. To obtain the normal time, the following equation is used.

$$Normal\ Time = \bar{X}\ x\ (1 + P)\ (5)$$

X = Average operating time
P = adjustment factor

The adjustment factor is the actual performance of the operator to complete a job. The adjustment factor is determined from the Westinghouse method.

After getting the normal time, then calculate the standard time with the formula:

$$Standard\ Time = Normal\ Time\ x\ \frac{100\%}{100\% - \%Allowance}\quad (6)$$

Information:
Allowance = allowance factor

By getting the standard time for each work element, the calculation of line balancing is continued, Line Balancing an operator completes the task in assembling in a balanced way in the production line (Salim & Hartanti, 2016). In balancing the trajectory, there are several common limiting factors, namely:

a. Precedence constraints.
   The limiting balance of the path is a technological barrier, the technological barrier in question is based on a predetermined work process or a process that can be carried out if it has completed a process (Baroto, 2002).
b. The minimum number of workstations (M) is 1, and the maximum is the number of operations (N).

$$1 \leq M \leq N \quad (7)$$

Line Balancing Method

In balancing the production line, there are methods that can be used, namely the *Ranked Positioned Weight* method and the *Region Approach* method.

1) Ranked Positioned Weight (RPW) Method

The Ranked Positioned Weight (RPW) method can also be said to be the Helgeson-Birnie method. This method was developed in 1961 by Helgeson and Birnie in General Electric. That value of the ranked positional weight is determined in each operation. The procedures are implemented in order to assign the operations into workstations (Eryuruk et al., 2008).

The steps for this method are determining the standard time and making a precedence diagram. Then, determining the weight of the operations on the precedence diagram as the 2nd step by starting with the last operation and calculating the weight of each operation. The grouping is done on the basis of the order of priority (weight) of the RPW (from the largest) and also by taking into account the limitations in the form of cycle time and the provisions of the order of operations in the precedence diagram.

The task strategy is proceeded until one of conditions underneath is obtained;

a) All the operations are already charged to the stations
b) There are no operations having uncharged time constraints

2) Region Approach Method

The Region Approach Method was created by Bedworth. This method divides the priority diagram into several regions vertically, and in each area, there is no dependency between work operations. In principle, the Regional Approach method seeks to preempt processes with enormous priority responsibilities (Nasution & Prasetyawan, 2008).

The steps were taken after measuring time-based on time study (Elsayed & Boucher, 1994):

a) Draw precedence diagrams.
b) Redraw the precedence diagram by moving the operation as much as possible to the far right.

c) For each precedence area, set the order of priority operations based on the operating time from the largest to the smallest.
d) Grouping operations into work stations based on the largest cycle time of work operations, this grouping must not exceed the predetermined cycle time.

Combination method

After sorting the work elements based on the Ranked Positioned Weight method and the Region Approach method, each method performs a performance calculation that can be used to evaluate the track balance, namely:

a) Idle Time

Idle time is to calculate the idle time that occurs in the workstation.

$$Idle\ time = n.Ws - \sum_{i=1}^{n} Wi \qquad (8)$$

Information:
Ws = Cycle Time
$\sum_{i=1}^{n} Wi$ = total working operating time

b) Production line efficiency (EL)

By determining the efficiency value of the production line, you will know the workstation has worked well or not, the higher the line efficiency value, the more efficient the track will be. Then the line efficiency formula is:

$$\frac{\sum STi}{K.CT}.100\% \qquad (9)$$

Information:
$\sum STi$ = total work station time
K = total number of workstations
CT = cycle time / longest cycle time

c) Balanced delay (BD)

The idle time balance value is the ratio of the total idle time related to the cycle time and the number of workstations. Then the formula for the balanced delay is:

$$\text{BD} = \frac{n.CT - \sum ti}{(n.CT)}.100\% \qquad (10)$$

Information:
n = number of workstations
CT = cycle time / longest cycle time
$\sum ti$ = total work station operating time

d) Smoothness Index

Smoothness Index/smoothing index is an index that shows the relative smoothness of the production line balancing, the following is the calculation of the smoothness index:

$$\text{(SI)} = \sqrt{\sum (STi_{maks} - STi)^2} \qquad (11)$$

Information:
STi = largest operating time
Where: Ti = operating time of the i-th workstation

RESEARCH METHODOLOGY

Field studies are needed in the ongoing research process in order to know firsthand the problems that must be investigated in the company. Observations made were direct observations from the first station to the last station, knowing the daily production scheduling target, knowing the data collection on the production results of several work stations and interviewing workers on the production floor to be more specific. After observing and interviewing the parties concerned, the problems experienced by the company were found, so in compiling the thinking of the literature that worked to add insight and knowledge to the problems that had been experienced previously, the problem solving was solved. Interviews were conducted with the parties concerned in the company, one of the companies interviewed was a sewing supervisor named Susi, a cutting supervisor named Rudi and a finishing supervisor named Susan who had worked at PT. Delapan Satu. The questions interviewed were about activities on the production floor regarding the ongoing production process. With these interviews, knowing the work station from the production floor, the work station in the production process has several elements of work carried out by an operator. After knowing the work elements of each work station, the data collection carried out was to measure the work elements from the production floor of PT. Delapan Satu. This method is carried out where the work elements are carried out following the ongoing production process. Collecting and processing the data will relate to the review literature review studied, so in problem for knowing productivity performance in time production could know worker in floor production work with effective or no so that influence capacity from floor production in a month. The data collection and processing will be related to the literature that has been studied, so that in time to determine the productivity of performance in production it can be seen that the production floor works effectively or does not affect the capacity of the production floor in a month

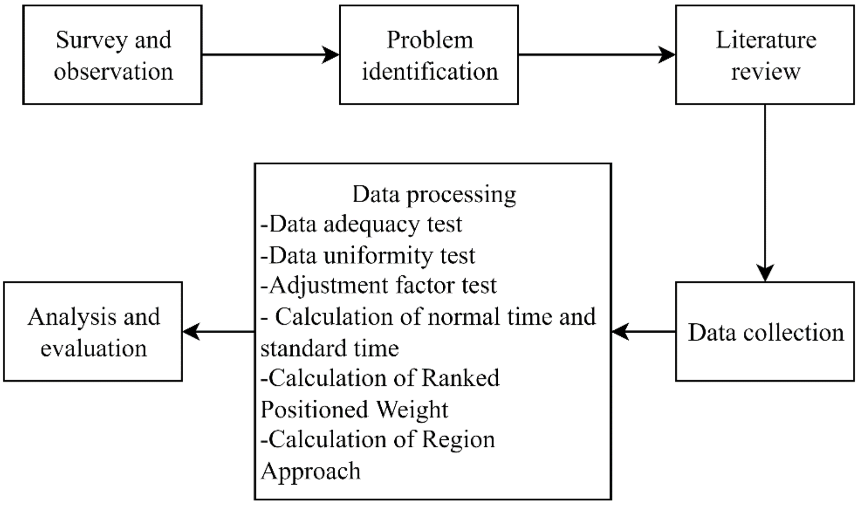

Figure 2. Framework of Study

FINDING AND DISCUSSION

PT. Batik Delapan Satu has a production process to produce finished garments. In the production process that takes place each work station has elements of work carried out to produce output, PT. Batik Eight Satu still uses human labor, resulting in different cycle times for each element. It can be seen from table 1, the remaining thread cutting element experienced a bottleneck which affected the production line.

Table 1.
Average Operating Time on Work Element

Workstation	No	Work Element	Average Operation Time (Second)
1	1	Cutting raw material	41,6
	2	Grouping of clothing patterns	12,4
2	3	Provide numbering for each clothing pattern	14,4

	4	Press	72,5
3	5	Sewing clothes pattern	38,1
	6	Sewing the whole outfit	53,0
4	7	Cutting the remaining thread	225,0
5	8	Doing ironing	113,7
6	9	Check the quality of clothes	154,1
7	10	Packaging	44,5

By getting the cycle time of the work elements from each station, measurements are taken to test the cycle time data. According to Rinawati, Puspitasari, & Muljadi (2012), uniformity tests and data adequacy tests are carried out to find out the data is uniform and the amount of data observed is sufficient. By getting the cycle time of the work elements from each station, measurements are taken to test the cycle time data. The uniformity test is carried out and resulted in the figures below:

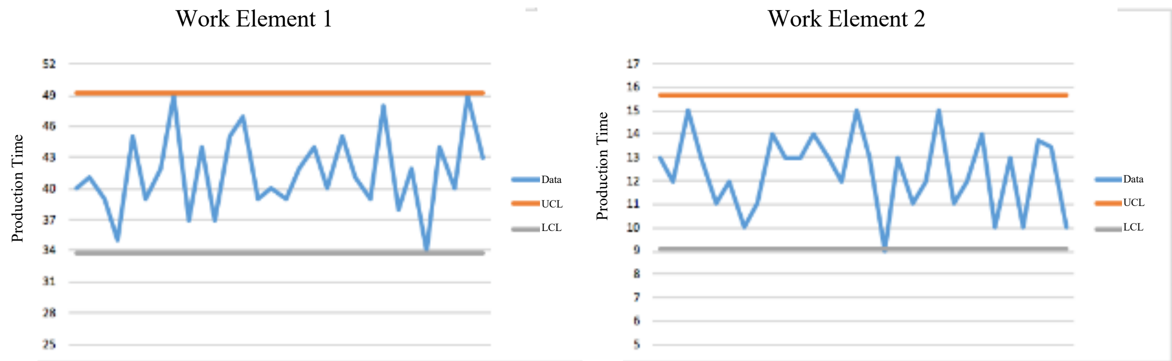

Figure 3. Uniformity Test of Work Element 1 and Work Element 2

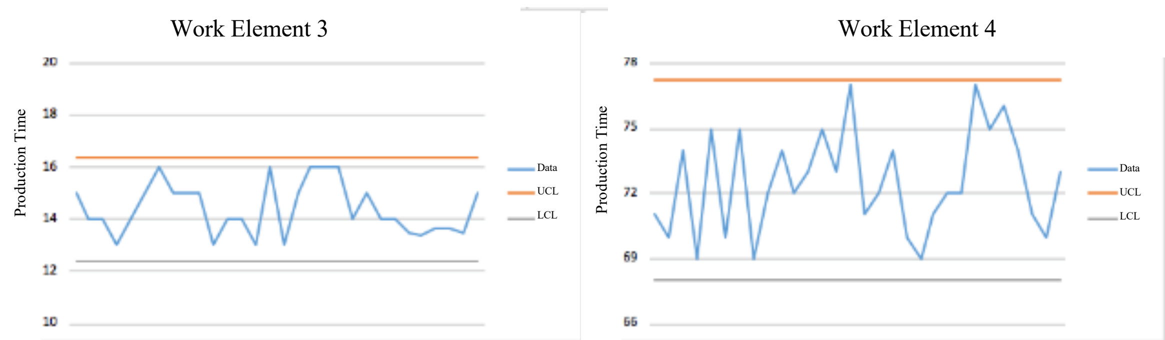

Figure 4. Uniformity Test of Work Element 3 and Work Element 4

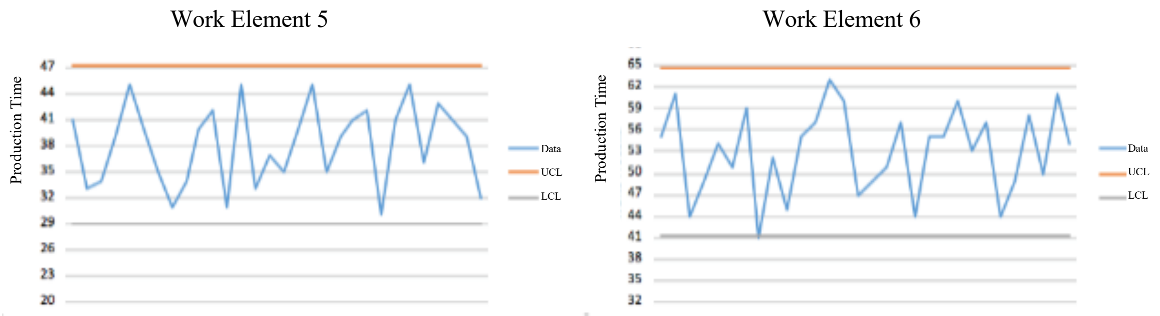

Figure 5. Uniformity Test of Work Element 5 and Work Element 6

Work Element 7 Work Element 8

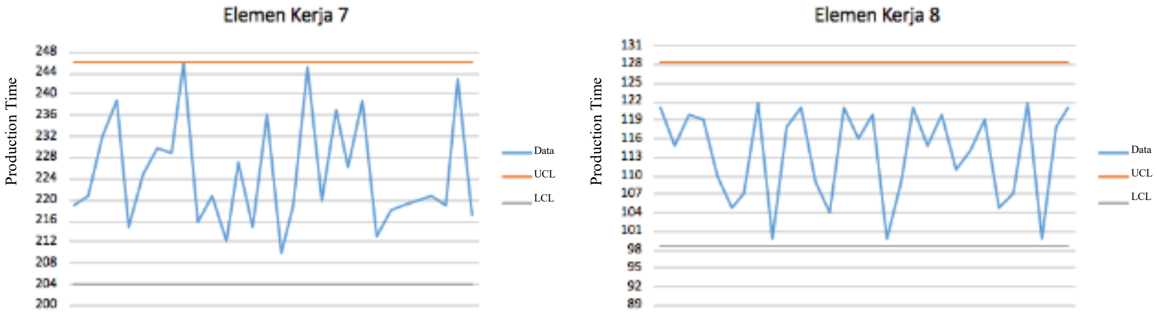

Figure 6. Uniformity Test of Work Element 7 and Work Element 8

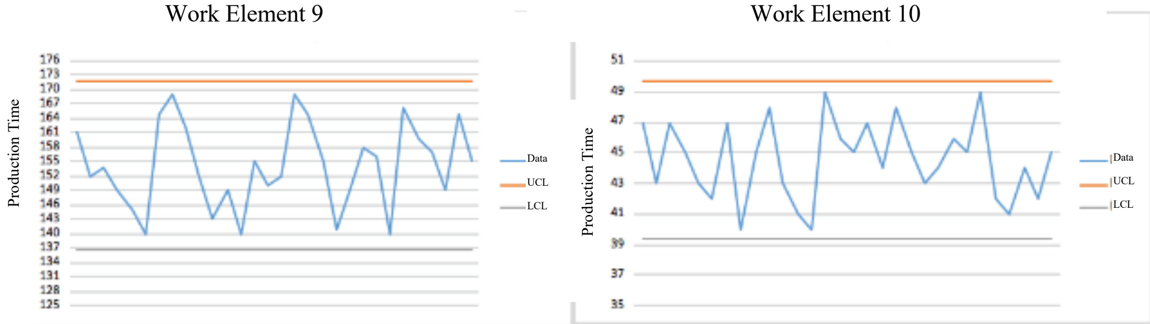

Figure 7. Uniformity Test of Work Element 9 and Work Element 10

The calculation of the data adequacy test for trimming work elements with a confidence level of 95%, if N' ≤ N it is stated that the amount of data is sufficient, whereas if N' > N it is stated that the amount of data is not sufficient (Barnes, 1980).

$$N' = \frac{40\sqrt{N\ \Sigma xi^2 - (\Sigma xi)^2}}{\Sigma \text{xi}} \quad (12)$$

$$N' = \frac{40\sqrt{30\ 52.269 - (1.247)^2}}{1247}$$

$N' = 13{,}44$

$N = 30$

$N' < N$, then the amount of data is sufficient.

Table 2.
Data Adequacy Test

Work Element	Σxi	Σ(Xi²)	N'	N	Conclusion
1	1247,00	52269,00	13,44	30	Sufficient
2	371,17	4669,13	26,79	30	Sufficient
3	431,17	6239,93	7,38	30	Sufficient
4	2167,00	157992,00	1,62	30	Sufficient
5	1144,00	44240,00	22,57	30	Sufficient
6	1590,00	85276,00	19,10	30	Sufficient
7	6749,00	1521391,00	3,26	30	Sufficient
8	3410,00	389192,00	6,56	30	Sufficient
9	4623,00	714629,00	5,00	30	Sufficient
10	1336,00	59686,00	5,10	30	Sufficient

After knowing that the data used is sufficient, measurements will be made using the time study method, the first step is to determine the adjustment factor for each work element:

Table 3.
Westinghouse Adjustment Factors

No.	Work Element	Adjustment								Total	Adjustment Factor
		Skills		Effort		Working Condition		Consistency			
1	Cutting raw material	B2	0,08	B2	0,1	C	0,02	B	0,03	0,21	1,21
2	Grouping of clothing patterns	B2	0,08	B2	0,1	C	0,02	A	0,04	0,22	1,22
3	Provide numbering for each clothing pattern	B2	0,08	B2	0,1	C	0,02	A	0,04	0,22	1,22
4	Press	C1	0,06	B2	0,1	D	0	B	0,03	0,17	1,17
5	Sewing clothes pattern	B2	0,08	B2	0,1	D	0	B	0,03	0,19	1,19
6	Sewing the whole outfit	B2	0,08	C1	0,1	C	0,02	B	0,03	0,18	1,18
7	Cutting the remaining thread	C1	0,06	C1	0,1	D	0	C	0,01	0,12	1,12
8	Doing ironing	B2	0,08	C1	0,1	C	0,02	C	0,01	0,16	1,16
9	Check the quality of clothes	B2	0,08	C1	0,1	C	0,02	B	0,03	0,18	1,18
10	Packaging	B2	0,08	C2	0	C	0,02	B	0,03	0,15	1,15

Table 4.
Normal Time of PT. Batik Delapan Satu

Workstation	No	Work Element	Average Operation Time (Second)	Adjustment Factor	Normal Time (Second)
1	1	Cutting raw material	41,6	1,21	50,30
	2	Grouping of clothing patterns	12,4	1,22	15,09
2	3	Provide numbering for each clothing pattern	14,4	1,22	17,55
3	4	Press	72,5	1,17	84,86
	5	Sewing clothes pattern	38,1	1,19	45,38
	6	Sewing the whole outfit	53,0	1,18	62,54
4	7	Cutting the remaining thread	225,0	1,12	251,96
5	8	Doing ironing	113,7	1,16	131,85
6	9	Check the quality of clothes	154,1	1,18	181,84
7	10	Packaging	44,5	1,15	51,21

Table 5.
Standard Time of PT. Batik Delapan Satu

No	Work Element	Normal Time (Second)	Allowance (%)	Standard Time (Second)
1	Cutting raw material	50,30	21,00	63,67
2	Grouping of clothing patterns	15,09	21,00	19,11
3	Provide numbering for each clothing pattern	17,55	28,50	24,55
4	Press	84,86	18,00	103,49
5	Sewing clothes pattern	45,38	21,00	57,44
6	Sewing the whole outfit	62,54	20,00	78,18
7	Cutting the remaining thread	251,96	20,00	314,95
8	Doing ironing	131,85	26,00	178,18
9	Check the quality of clothes	181,84	25,00	242,45
10	Packaging	51,21	21,00	64,83

After getting the standard time for each work element, then do a line balancing calculation in order to balance the production line at PT. Batik Delapan Satu, here is the precedence diagram of PT. Batik Delapan Satu.

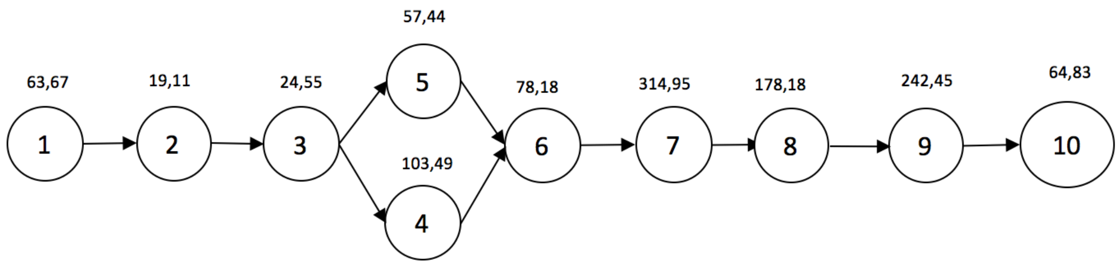

Figure 8. Precedence Diagram of PT. Batik Delapan Satu

After knowing the precedence diagram from PT. Batik Delapan Satu, then carried out the design of the assembly line using the RPW method. In the RPW method, the first step that must be done is to sort the operations based on the weight of each existing operation.

Table 6.
Elements of Work by RPW Method

No	RPW	Work Element Minimum Ratio (Second)	Previous Element
1	1146,84	63,67	-
2	1083,18	19,11	1
3	1064,07	24,55	2
4	982,08	103,49	3
5	936,03	57,44	3
6	878,59	78,18	4,5
7	800,41	314,95	6
8	485,46	178,18	7
9	307,28	242,45	8

10	64,83	64,83	9

Table 7.
Work Elements in Workstations According to the RPW Method

Workstation	Work Element	Work Element Minimum Ratio (Second)	Cumulative time	Total Workstation Time (second)	Idle Time (Second)	Workstation Efficiency (Second)
1	1	63,67	1146,84	268,26	46,70	85,17
	2	19,11	1083,18			
	3	24,55	1064,07			
	4	103,49	982,08			
	5	57,44	936,03			
2	6	78,18	878,59	78,18	236,78	24,82
3	7	314,95	800,41	314,95	0,00	100,00
4	8	178,18	485,46	178,18	136,77	56,57
5	9	242,45	307,28	307,28	7,68	97,56
	10	64,83	64,83			

The calculation for RPW method:

1. *Idle Time* = $n.Ws - \sum_{i=1}^{n} Wi = 5.(314{,}95) - 1146{,}84 = 7{,}345$
2. *Balance Delay* = $\frac{n.CT - \sum ti}{(n.CT)}.100\% = \frac{5.(314{,}95) - 1146{,}84)}{(5)(314{,}95)}.100\% = 27{,}17\%$
3. *Line Efficiency* = $\frac{\sum STi}{K.CT}.100\% = \frac{1146{,}84}{(5)(314{,}95)}.100\% = 73{,}83\%$
4. *Smoothness Index* = $\sqrt{\sum(STi_{maks} - STi)^2} = 277{,}51$

In the Region Approach method, the step that must be done is to recreate the precedence diagram by shifting to the right all existing operations. The leftmost operation is the predecessor operation and the far-right process has no followers. The following is a precedence diagram using the Region Approach method.

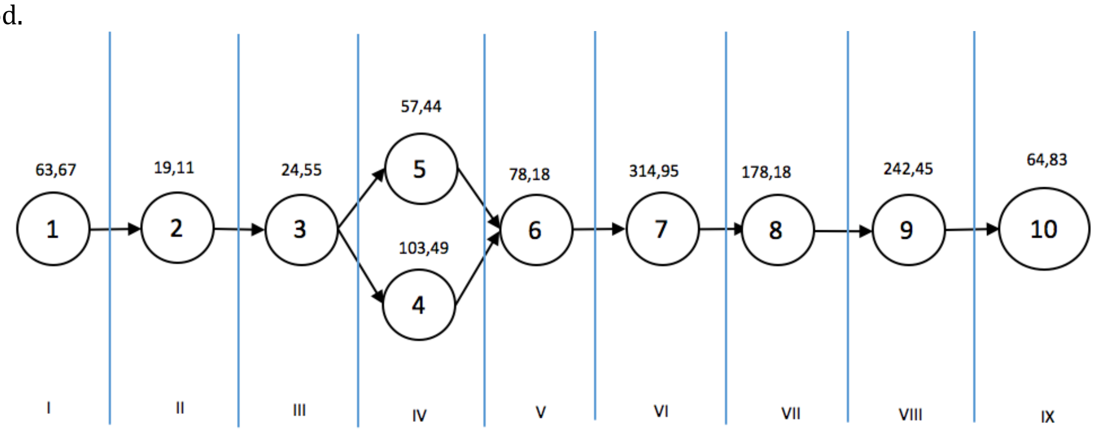

Figure 9. Precedence Diagram for Region Approach Method

After the precedence diagram is made and the area is clearly visible, then the process of sorting operations is carried out. The following is a recapitulation of operations and regions using the Region Approach method.

Table 8.
Work Elements by Region Approach Method

Work Element	Column	Work Element Minimum Ratio (Second)	Previous Element
1	I	63,67	-
2	II	19,11	1
3	III	24,55	2
4	IB	103,49	3
5	IV	57,44	3
6	V	78,18	4,5
7	VI	314,95	6
8	VII	178,18	7
9	VIII	242,45	8
10	IX	64,83	9

The following is a recapitulation of workstations using the Region Approach method.

Table 9.
Work Elements in Work Stations by Region Approach Method

Workstation	Work Element	Work Element Minimum Ratio (Second)	Total Workstation Time (second)	Idle Time (Second)	Workstation Efficiency (Second)
1	1	63,67	268,26	46,70	85,17
	2	19,11			
	3	24,55			
	4	103,49			
	5	57,44			
2	6	78,18	78,18	236,78	24,82
3	7	314,95	314,95	0,00	100,00
4	8	178,18	178,18	136,77	56,57
5	9	242,45	307,28	7,68	97,56
	10	64,83			

Calculations for the Region Approach method:
1. *Idle time* = $n.Ws - \sum_{i=1}^{n} Wi = 5.(314{,}95) - 1146{,}84 = 7{,}345$
2. *Balance Delay* = $\frac{n.CT - \sum ti}{(n.CT)}.100\% = \frac{5.(314{,}95) - 1146{,}84)}{(5)(314{,}95)}.100\% = 27{,}17\%$
3. *Line Efficiency* = $\frac{\sum STi}{K.CT}.100\% = \frac{1146{,}84}{(5)(314{,}95)}.100\% = 73{,}83\%$
4. *Smoothness Index* = $\sqrt{\sum(STi_{maks} - STi)^2} = 277{,}51$

Calculations for the initial conditions of the company:
1. *Idle time* = $n.Ws - \sum_{i=1}^{n} Wi = 7.(314{,}95) - 1146{,}84 = 1057{,}83$
2. *Balance Delay* = $\frac{n.CT - \sum ti}{(n.CT)}.100\% = \frac{7.(314{,}95) - 1146{,}84)}{(7)(314{,}95)}.100\% = 47{,}98\%$
3. *Line Efficiency* = $\frac{\sum STi}{K.CT}.100\% = \frac{1146{,}84}{(7)(314{,}95)}.100\% = 57{,}02\%$
4. *Smoothness Index* = $\sqrt{\sum(STi_{maks} - STi)^2} = 468{,}68$

Table 10.
Recapitulation of Ranked Position Weight and Region Approach Methods

No	Criteria	Company Initial Condition	RPW Method	RA Method
1	Number of Workstations	7	5	5
2	Balance Delay	47,98	27,17	27,17
3	Production Line Efficiency	52,02	73,83	73,83
4	Smoothness Index	468,68	277,51	277,51
5	Idle Time	1057,83	427,92	427,92

1. CONCLUSION AND FURTHER RESEARCH

Based on the data analysis, to get the efficiency of the production line at the initial conditions of PT. Batik Delapan Satu, which is 52.02%, after the proposed work station using the Ranked Positional Weight method and the Region Approach method, the efficiency of the production line becomes 73.82%. With the Ranked Positional Weight method and the Region Approach method, the production line effectively minimizes bottlenecks, reducing workstations at PT. Batik Eight Satu became five workstations which initially had seven workstations. With 5 working stations, the idle time of each station will be reduced, namely the idle time in the company's initial conditions of 1057.83 seconds to 427.92 seconds.

Suggestions are given to the company, namely, to provide a comfortable place so that the measurement process runs without obstacles. Each operator at each workstation must know what operations are carried out at their respective stations. The equations used to process the data should be determined correctly in advance to facilitate the data processing and produce accurate data to perform other calculations

REFERENCES

Apriyono, A., & Taman, A. (2013). *Jurnal Nomina / Volume Ii Nomor Ii / Tahun 2013 76 Analisis Overreaction Pada Saham Perusahaan Manufaktur Di Bursa Efek Indonesia (Bei) Periode*. *II*, 76–96.

Arifiana, G. S., and Suletra, I. W. (2017) *Analisis Line Balancing dengan RPW pada Departemen Sewing Assembly Line Style F1625W404 di PT. Pan Brothers*. Boyolali. Surakarta: Universitas Sebelas Maret.

Barnes, Ralph M. (1980) Motion and Time Study: Design and Measurement of Work. New York: John Willey and Sons.

Baroto, T. (2002). *Perencanaan dan Pengendalian Produksi*. Jakarta: Ghalia Indonesia.

Basuki, M., MZ, H., Aprilyanti, S., & Junaidi, M. (2019). *Perancangan Sistem Keseimbangan Lintasan Produksi dengan Pendekatan Metode Heuristik* (Vol. XI). Palembang: Universitas Tridinanti Palembang.

Chen, J. C., Chen, C. C., Su, L. H., Wu, H. Bin, & Sun, C. J. (2012). Assembly line balancing in garment industry. *Expert Systems with Applications*, *39*(11), 10073–10081. https://doi.org/10.1016/j.eswa.2012.02.055

Elsayed, A. and Boucher, Thomas O. (1994) *Analysis and Control of Production Systems Second Edition*. New Jersey: Prentice-Hall International, Inc.

Ekoanindiyo, F. A., & Helmy, L. (2017). *Meningkatkan Efisiensi Lintasan kerja Menggunakan Metode RPW dan Killbridge-Western* (Vol. X). Semarang: Universitas Stikubank.

Eryuruk, S. H., Kalaoglu, F., & Baskak, M. (2008). Assembly line balancing in a clothing company. *Fibres and Textiles in Eastern Europe*, *16*(1), 93–98.

Firake, S. T., & Inamdar, K. H. (2014). Productivity Improvement of Automotive Assembly Line Through Line Balancing. *International Journal of Technical Research and Applications*, *2*(3), 124–128.

Fudianto, D., & Munir, M. (2017). *Rancangan Keseimbangan Stasiun Kerja Guna Meningkatkan Efesiensi Waktu Siklus Operasi Produksi Es Balok.* Pasuruan : Universitas Yudharta Pasuruan

Juwita , R. S. (2004). Peningkatan Kapasitas Produksi dengan Perbaikan Metode Kerja dan Pengalokasian Tenaga Kerja di CV. Waru Indah.

Karmawan, M. P., Pulansari, F., and Donoriyanto, D. S. (2020) *Analisis Line Balancing Menggunakan Metode Largest Candidate Rule, Killbrigde and Western Method, dan Ranked Positional Weight Method di PT. XYZ*. Surabaya: Universitas Pembangunan Nasional Veteran Jawa Timur.

Mengistu, M. (2019). Line Balancing Techniques for Productivity Improvement. *International Journal of Mechanical and Industrial Technology*, *7*(1), 89–104. https://www.researchgate.net/publication/333310098_Line_Balancing_Techniques_for_Productivity_Improvement

Nasution, A. H., & Prasetyawan, Y. (2008). *Perencanaan dan pengendalian produksi*. Graha Ilmu.

Plenert, G. (1997). Line balancing techniques as used for just-in-time (JIT) product line optimization. *Production Planning and Control*, *8*(7), 686–693. https://doi.org/10.1080/095372897234795

Rinawati, D. I., Puspitasari, D., and Muljadi, F. (2012) *Penentuan Waktu Standart dan Jumlah Tenaga Kerja Optimal Pada Produksi Cap.*

Salim, H., Setiawan, K., and Hartanti, L. (2016) *Perancangan Keseimbangan Lintasan Produksi menggunakan Pendekatan Simulasi dan Metode Ranked Positional Weights (Vol. XI).*

Trenggonowati, D. L. and Febriana, N. (2019) *Mengukur Efesiensi Lintasan dan Stasiun Kerja Menggunakan Metode Line Balancing Studi Kasus PT. XYZ (Vol. IV).* Cilegon: Universitas Sultan Ageng Tirtayasa Cilegon.

Wignjosoebroto, S. (2008). *Ergonomi Studi Gerak dan Waktu*. Guna Widya.

Yulianti, D. (2018). *Analisa Penyeimbangan Lintasan Perakitan pada Proses Pembuatan T-Shirt di Departemen Assembling dengan Menggunakan Metoda Hegelson - Birnie dan MetodaKillbridge – Wester PT. Caladi Lima Sembilan (C-59) Bandung* (Vol. XII). Bandung: Universitas Bandung Raya.