Reduction of Bottleneck in the Jacket Production Process in the Sewing Department using Line Balancing Method

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ABSTRACT
Line Balancing is an assignment of several jobs to the production line or related work stations within the line to minimize idle time. PT ABC is a company engaged in the garment industry that produces products such as Pants, Board shorts, Men-shirts, Ladies wear, T-shirts, Polo shirts and Jackets. The production system used by PT ABC is Make to Order. The company will produce according to the buyer's request. Samples that have been approved will soon be mass-produced. Every day the company produces different products in each line with different targets. Production targets are often not achieved and bottlenecks occur at several work stations, such as in line 2 which produces products in the form of jackets with X style. Therefore, a research was conducted on that line. This study aims to determine the amount of idle time, efficiency, and delay time before and after repairs to determine the optimal work station in the production process of the sewing line 2 department to minimize the occurrence of bottlenecks. This research was conducted using the Regional Approach method. The results of this study resulted in a balanced track design with the number of work stations needed as many as 37 units with an idle time of 5,871.2 seconds, a balance delay of 50.8%, a track efficiency of 49.19% and a smoothness index of 76.59 and an increase in track efficiency which was originally 40.44% to 49.19%.

Keywords: *Line Balancing, Regional Approach, Workstation Efficiency, Bottleneck*

1. INTRODUCTION

Line balancing is an assignment of a number of jobs into interrelated work stations in one line or production line (Baroto, 2002). Line balancing is a group of people or machines that perform sequential tasks in assembling a product in a balanced manner so that work efficiency is achieved [1]. Line balancing is concerned with mass production by clustering in several work centers or work stations [2]. If a work station with processing time is below the predetermined time limit, it can cause idle time and buildup at the work station (bottleneck). The purpose of track balance is to balance the track and make the work station more efficient so that it can produce optimal output [3]. Technically, track balance is done by distributing each work element to work stations with reference to cycle time [4]. The Regional method was developed by Berdworth after the positional weighting method [5]. The Region Approach method is used to complement the shortcomings of the Ranked Possitional Weight method, namely in processes that have many branches, grouping in regions (columns) must be carried out and then work stations are formed (Burhan et al, 2012). This method is done by dividing the precedence diagram region into several regions and prioritizing the operation that has the largest operating time. This technique is a heuristic procedure, where the selection of elements to be placed on a work station is based on the position of the elements in the precedence diagram [6].

As a supply chain of textile industry, garment industry is one of the major industries of the world. The production process of garments is separated into four main phases: designing/ clothing pattern generation, fabric spreading and cutting, sewing and ironing, and packing [7]. PT ABC is a Make to Order (MTO) company where this company will produce products according to buyer requests. In carrying out the production process, this company has a production target according to a working time of 8 hours / day and this production target will be different for each line and different style. One of the most influential factors on the company's productivity is the production line [8]. However, companies often do not achieve production targets or do not fulfill orders so that production is considered less than optimal. This unfulfilled production target was caused by the build-up at work stations, the difficulty level of the styles being produced, and the different abilities of operators. Assigning different work items causes different amounts of unproductive time and variations in the number of workers required for production (Dini, 2018). This company also applies a discount system, where if the product produced exceeds the specified time limit, the more discounts the company gives to buyers and this can be detrimental to the company. Companies must overcome the buildup and increase productivity at each work station in the sewing process.

The production process is the main thing in a manufacturing company, therefore the balance of the production line and the planning of the number of work stations used must be as minimal as possible, it is expected to increase production efficiency and effectiveness which ultimately provides optimal results for the company (Jaka, 2008). This research was conducted with the aim of knowing the amount of idle time, efficiency, and delay time to determine the optimal work station in the production process of the sewing line 2 department so as to minimize the occurrence of bottlenecks. The benefit of doing this research is to produce a proposal to overcome bottlenecks in the sewing jacket style X process in line 2 production so that the expected output can be more optimal than the previous output.

2. METHODS

This research is carried out by collecting what will be needed. data retrieval methods are divided into how to collect data and input data received directly from the company. Data collection can be done by means of observation and interviews during the study. Observation is an activity to observe every process that occurs. Interviews with sewing operators, Industrial Engineering department staff and practical work supervisors. Then the author can take input data such as primary and secondary data. Primary data taken by researchers in the form of data directly taken from the time of observation. The data such as data cycle time and the number of operators in the production line. Secondary data is data taken from other references, such as journals, books and scientific works.

The data processing carried out in the study include:

1. Measure the cycle time 3 times in each assembly process.
2. Conduct adequacy test and data uniformity test.
3. Calculating cycle time, normal time and standard time
4. Calculate idle time, delay time, efficiency and smoothness index.
5. Summarize the efficiency of existing work stations.

3. RESULT AND DISCUSSION

In this study, the authors collect the necessary data by observing directly the assembly process of the Style X jacket product on the production Line 2 of the Sewing Department of PT ABC. The data taken in the form of cycle time from each process at each work station. Data retrieval using the stop clock method with 3 repetitions. In the assembly process of the Style X jacket product, there are 45 work stations. Precedence diagrams are made with the aim of making it easier to see the flow of operations in the production process. Precedence diagram is a graphical depiction that starts from work operations, and has a dependence on other work operations which have the aim of making it easier to control and plan related activities in it [9].

3.1 Data processing

3.1.1 Test of Sufficiency and Uniformity of Data

Based on the data collection above where observations were made on the cycle time of each process with 3 repetitions. Then a test of the adequacy and uniformity of the data will be carried out which is to ensure that the data taken is sufficient or not and the uniformity of the data taken. The following is an example of calculating the adequacy and uniformity of the data in the Join Side process with the initial data, which can be seen in Table 1.

Table 1 Join Side process time data

Iterasi	**X**	**X²**	X-$\bar{X}$	(X-$\bar{X}$)²
1	156	24.336	-3	9
2	153	23.409	-6	36
3	168	28.224	9	81
Total	477	75.969	0	126
$\bar{X}$	159			

1. Data Sufficiency Test

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\ \sum x^2 - (\sum x)^2}}{\sum x}\right] = \left[\frac{\frac{2}{0{,}05}\sqrt{3\ (75.969) - \ (477)^2}}{477}\right] = \ 2{,}65$$

Based on the data adequacy test above, the value of N' is 2.65. Thus, N' < N and it is concluded that this data is considered 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 (Chang et al, 2022).

2. Data Uniformity Test

The data uniformity test was carried out to find out whether from the data taken there was no data uniformity. This will be proven through the limits that have been determined, if it exceeds the limit, then the data is considered non-uniform. The following is the calculation of the data uniformity test from the side join process.

$$\sigma = \sqrt{\frac{\sum(x - \ \bar{x})^2}{N-1}} = \sqrt{\frac{126}{2}}$$

$$BKA = \ \bar{x} + k.\sigma \ \ = \ 159 + 2\ .7{,}94 = \ 174{,}875$$

$$BKB = \ \bar{x} - k.\sigma \ = \ 159 - 2\ .7{,}94 = \ 143{,}125$$

Based on the calculation, the data is declared uniform.

3.1.2 Calculating Cycle Time, Normal Time and Standard Time.

1. Calculating Cycle time

Cycle time Is time needed to make one product unit in a work station [10]. The following is a calculation of the cycle time in the Join Side process

$$W = \frac{\sum observation\ time}{\sum iteration} = \frac{477}{3} = 159\ seconds$$

2. Calculating normal time

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Calculating normal time is done by considering the adjustment factor (factory rating). In measuring the adjustment factor, 2 methods are used, namely the Westinghouse method and the objective method. The following is the calculation of the adjustment factor.

Westinghouse Method:

Skill	: Good C1	= +0.06
Work	: Excellent B2	= + 0.08
Working condition	: Good C	= + 0.02
Consistency	: Good C	= + 0.01
Total		= + 0.17

Therefore :

P1 = 1 + 0.17 = 1.17

Objective Method:

Members used	: upper arm, forearm, etc.	= 5
Foot pedal	: No pedal	= 0
Use of hands	: Both hands help each other	= 0
Eye coordination	: Constant and close	= 4
Equipment	: Need control and suppression	= 2
Weight	: B-1 (0.45)	= 2
Total		= 13

P2 = 1 + (13/100) = 1.13

Then the rating factor value of the Join Side operation is

P = P1 x P2 = 1.32

Thus, the normal time of the Join Side operation is

$$Wn = Ws\ x\ P\ = 159\ x\ 1{,}32\ = 209{,}88\ seconds$$

3. Calculating standard time

Standard time is calculated by considering the existing allowances. The allowance given by the company in each operation is 10%. The following is a calculation of the standard time for side join operations.

$$Wb = Wn\ x\ \frac{100\ \%}{100\ \% - Allowance} = 209{,}88\ x\ \frac{100\ \%}{100\ \% - 10\ \%} = 233{,}2\ seconds$$

3.1.3 Calculating Initial Condition Efficiency

Based on observations in the assembly process for making Jacket Style X, obtained data before balancing the track using the Regional Approach method. The following is a calculation of the efficiency at the initial conditions at each work station.

a. Efficiency calculation at work station 4

$$Eff = \frac{Wi}{Ws\ max}\ x\ 100\ \%$$

$$Eff = \frac{117{,}7}{312{,}3}\ x\ 100\ \%$$

$$= 37{,}69\ \%$$

b. Idle time at work station 4

$$IT\ = n\ x\ Ws - \sum Wi$$

$$IT\ = 45\ x\ 312{,}3 - 5.684{,}08$$

$$IT\ = 14.053{,}5 - 5.684{,}08$$

$$IT\ = 8{,}369{,}42\ seconds$$

c. Balance Delay time at work station 4

$$BD = \frac{n.Ws - \sum Wi}{n.Ws}\ x\ 100\ \%$$

$$BD = \frac{(45\ x\ 312{,}3) - 5.684{,}08}{45\ x\ 312{,}3}\ x\ 100\ \%$$

$$BD = 59{,}55\ \%$$

d. Line efficiency

$$Eff\ line = \frac{\sum Wi}{n.Ws}\ x\ 100\ \%$$

$$Eff\ line = \frac{5.684,08}{45\ x\ 312,3}\ x\ 100\ \%$$

$$Eff\ line = 40,44\%$$

e. Smothness Index

$$SI = \sqrt{\sum (Ws - Wi)^2}$$

$$SI = \sqrt{8.369,42}$$

$$= 91,48$$

3.1.4 Comparing cycle time with takt time

From the cycle time data that has been calculated based on observations on the jacket product assembly process on line 2, a comparison will be made against the takt time. Comparison of cycle time with takt time can be seen in Figure 1.

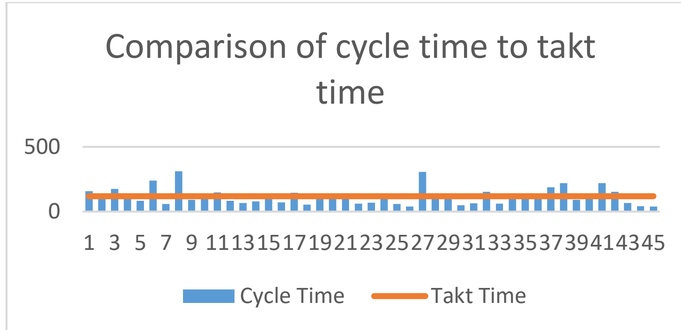

Figure 1. Comparison graph of cycle time and take time

3.1.5 Calculating Line Balancing with Regional Approach Method

1. Territory Division and Calculating optimal cycle time

The following is a regional division and optimsl cycle time for the entire jacket style X assembly process which can be seen in Table 2.

Table 2. Optimal cycle time

Region	Operation Name	Ws (second)	Total Ws per operation (second)	Ws Maks (second)	Efficiency Work Station (%)
I	Side join	159	159	312,3	50,9
II	Tindes joins side	125	125	312,3	40
III	Shoot join side	174,3	174,3	312,3	55,8
IV	Top pocket	117,7	117,7	312,3	37,69
	Heming top pocket	84,33			
V	Join interlinig + inner flap pocket	91,33	275,96	312,3	88
	Make flap finish	100,3			
VI	Install tunnel waist tires	239,3	239,3	312,3	77
VII	Cup nut top pocket	58	195	312,3	62
	Blabar flap pocket inside	137			
VIII	Kress & install top pocket	312,3	312,3	312,3	100
	Tindes blabar inner flap pocket	147,3			
IX	Create inner flap	84,33	299,3	312,3	96
	Join interlinig + outer flap pocket	67,67			
X	Install inner & outer flaps	79,67	151,34	312,3	48
	Kepras flap finish	71,67			
XI	Tindes flap finish	146,3	146,3	312,3	47
XII	Sewing help flap finish	53,67	53,67	312,3	17
XIII	Install the flap pocket	136,7	136,7	312,3	44
XIV	Tindes install flap pocket	119	119	312,3	38
XV	Put on the hood	127	127	312,3	41
XVI	Join the shoulders	60,67	119,67	312,3	38
	Heming facing	59			
XVII	Shoulder tints	68,67	109	312,3	35
	Overhead facing	40,33			
XVIII	Shot the shoulder	108,3	108,3	312,3	34,7
XIX	Kress & attach zipper	306,7	306,7	312,3	98,2
XX	Kress & install facing	124,7	124,7	312,3	39,9
XXI	Tindes placket	124,7	124,7	312,3	39,9
XXII	Sewing help plaques	50,33	50,33	312,3	16,1
XXIII	Taking e.string hood	63,67	63,67	312,3	20,4
XXIV	Heming facing hood	152	152	312,3	48,7
XXV	Kepras neck	60,62	60,62	312,3	19,4
XXVI	Install sleeves (2)	140,7	140,7	312,3	45,1
XXVII	Funnel neck	108,7	108,7	312,3	34,8
XXVIII	Overlock armhole (2)	135,7	135,7	312,3	43,5
XXIX	Tindes armhole (2)	188,7	188,7	312,3	60,4
XXX	Install interlining + button	220,3	220,3	312,3	70,5
XXXI	Install the button + vecnt	91,67	91,67	312,3	29,4
XXXII	Kress & put the button	120	120	312,3	38,4
XXXIII	Tindes edge bottom	221	221	312,3	70,8
XXXIV	Tindes front & hood	152,7	152,7	312,3	48,9
XXXV	Heming bottom	204,3	204,3	312,3	65,4
XXXVI	Install the placard	129,7	129,7	312,3	41,5
XXXVII	Tindes put up plaques	123,3	123,3	312,3	39,5

a. Efficiency calculation at work station 4

$$Eff = \frac{Wi}{Ws\ max}\ x\ 100\ \%$$

$$Eff = \frac{117,7}{312,3}\ x\ 100\ \%$$

$$= 37,69\ \%$$

b. *Idle time* at work station 4

$$IT\ = n\ x\ Ws - \sum Wi$$

$$IT\ = 37\ x\ 312,3 - 5.684,08$$

$$IT\ = 11.555,1 - 5.684,08$$

$$IT\ = 5.871,2\ seconds$$

c. Balance delay time at work station 4

$$BD = \frac{n.Ws - \sum Wi}{n.Ws}\ x\ 100\ \%$$

$$BD = \frac{(37x\ 312,3) - 5.684,08}{37\ x\ 312,3}\ x\ 100\ \%$$

$$BD = 50,8\ \%$$

d. Line efficiency

$$Eff\ line = \frac{\sum Wi}{n.Ws}\ x\ 100\ \%$$

$$Eff\ line = \frac{5.684,08}{37\ x\ 312,3}\ x\ 100\ \%$$

$$Eff\ line = 49,19\%$$

e. Smothness Index

$$SI = \sqrt{\sum (Ws - Wi)^2}$$

$$SI = \sqrt{5.866,7}$$

$$= 76,59$$

2 Summary of work efficiency

The summary of work efficiency during the initial conditions and after using the Regional Approach method can be seen in Table 3

Table 3 Summary of work efficiency

Methods	Ws (second)	Number of Workstations	Idle Time (second)	Balance Delay	Line Efficiency (%)	Smoothness Index
Initial Conditional	312,3	45	8.369,42	59,55	40,44	91,48
Regional Approach	312,3	37	5.871,2	50,8	49,19	76,59

Based on the work efficiency summary, the path improvement using the Regional Approach method has a higher path efficiency than the initial condition, which is 49.19% with a total of 37 work stations. So that the optimal precedence path diagram can be seen in Figure 2.

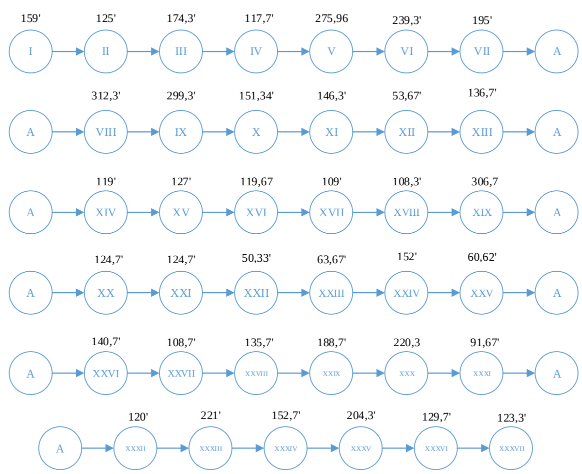

Figure 2. Precedence diagram optimal

4. CONCLUSION

Based on the research and data processing carried out, it can be concluded that the optimal number of work stations after using the regional approach is 37 compared to the initial conditions of 45 work stations. The idle time obtained after repair is 5,871.2 seconds, indicating a decrease from the previous condition. The percentage of the balance delay after the repair has decreased by 50.8% from the previous 59.55%. The efficiency of the improved track has increased from 40.44% to 49.19%. The decline in the smoothness index after the improvement was 76.59 from 91.48. The advice that can be given by the author based on the results of research that has been done is that line balancing in a production process is needed to minimize the occurrence of idle time, so that optimal production targets can be achieved. The operator's ability affects the production target so there must be an increase in the performance of the skills of each operator. The existence of training and training time in accordance with the time that is considered capable of making performance capabilities as desired by the company and will not hamper the production process. Strict supervision of the ongoing production process must be carried out in order to increase the work efficiency of each operator.

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