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Case Study

The Analysis of Production Line Balance Using the Moodie Young Method at X Inc.

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ABSTRACT

The goal of this study is to determine how much the level of efficiency the production line at PT. X by using the Moodie young approach. The three components of the method - Line Efficiency, Balance Delay, and Smooth Index - are utilized to assess the degree of balance in the manufacturing line. The findings indicated that there were 5 work stations with 7 work elements in the real production line configuration, with a Line Efficiency of 40.29%, a Balance Delay of 59.70%, and a Smoothness Index of 9578.22. As a consequence of the research utilizing the Moodie Young approach, the new production lines are composed of 3 work stations with 7 work elements and a Line Efficiency result of 67.15%, Balance Delay of 32.84%, and Smoothness Index of 4449.71.

Keywords: Line Balancing, Moodie Young, Line Efficiency, Balance Delay, Smooth Index

INTRODUCTION

The development of the business world has forced industry players to come up with innovative ideas to produce maximum products both in terms of quality and quantity. Hence, every industry must strive to maintain stability (Haseeb et al., 2019). However, an issue with imbalance in the production process frequently occurs, taking a long time to accomplish a task. Production line balance is closely related to mass production. A number of production jobs are grouped into several work centres. The pace of the production line determines how long is permitted to finish the job part. Every work station has a cycle time that is as uniform as possible. A work station will have an interruption time if the time is less than the desired cycle time (Zupan & Herakovic, 2015). Since the output is defined by the longest operation, which makes other operations wait, problems that are resolved on the remaining portions of the production line reduce idle time on the line. Because of this, there are inefficiencies in the use of the equipment and the operators, which results in a decrease in output and a waste of production capacity (Eunike et al., 2021).

When some workstations are idle while others are still staffed full-time, there is an imbalance in the production activity throughout the line. This results from the work station taking longer than the planned production line speed to accomplish a task. The capacity level, demand, and longest running period all influence speed (Fitri et al., 2022). The existing processes on the production floor are considered to be still not optimal due to an imbalance in the production process which results in a long time to complete a job. Similar to work element 3, it has the largest and longest manufacturing process, which causes a build-up of raw materials and idle time for the following work element (Trenggonowati & Febriana, 2019). Given the foregoing context, it is clear that the challenge is formulated as: What is the present level of production line efficiency at X Inc? In addition, this study also attempts to determine how effective the production line at X Inc. employing the Moodie Young approach.

MATERIALS & METHODS

This research was conducted at X Inc. which is located in Medan, North Sumatra. The type of research used is a case study which is applied to understand a problem more deeply by observing directly in the field in an integrative and comprehensive manner (Walliman, 2017). The data used in this study are Primary Data and Secondary Data. The Moodie young approach is used to process the data on the balance of this production line. One approach to production line balance that can address issues with line balance and produce outcomes that are almost as efficient is the Moodie young approach (Haming, 2022). The steps for data processing are as follows.

1. Test the adequacy of the data, by using the Equation (1)

$$N' = \left(\frac{\frac{k}{s}\sqrt{N(\sum x^2) - (\sum x)^2}}{(\sum x)}\right)^2 \quad (1)$$

2. Test the uniformity of the data, by using the Equation (2)

$$UCL = X + k(\sigma)$$
$$LCL = X - k(\sigma) \quad (2)$$
$$\sigma = \frac{\sqrt{\sum(x - xi)^2}}{N - 1}$$

3. Calculate normal time, by using the Equation (3)

$$Wn - i = Xi\,.RFi \quad (3)$$

4. Calculate standard time, by using the Equation (4)

$$Wb - i = Wn - i\,.\frac{100}{100 - (All)i} \quad (4)$$

5. Determine the duty cycle time by using the Equation (5)

$$ti\ max \leq CT \leq \frac{P}{Q} \quad (5)$$

6. Calculation of line efficiency, balance delay, smooth index on the actual track and the Moodie young track, including:

a. Line efficiency

$$LE = \frac{\sum_{m=1}^{6}(ST)_m}{(K)(CT)}100\% \quad (6)$$

b. Balance Delays

$$D = \frac{(K.CT) - \sum_{j=1}^{n} t_j}{(K.CT)}100\% \quad (7)$$

c. Smooth Index

$$SI = \sqrt{\sum_{m=1}^{k}[(ST)_{max} - (ST)_m]^2} \quad (8)$$

RESULT

Data Adequacy Test. To determine if the data obtained is sufficient or not, the data adequacy test calculation is necessary to be conducted. If N' < N, the data are considered satisfactory and no further information is required. However, if N' > N, it is argued that there is inadequate data and more data is required (Sugiyono, 2019). Using the weight of raw materials as an example of the first work element, calculate the data adequacy test by using Equation (1). An example of calculating the data adequacy test for the first work element, namely weighing raw materials.

Table 1. Recapitulation of Data Adequacy Test for Each Work Element.

Work Element	N'	N	Status
1	0,0009	7	Adequate
2	0	7	Adequate
3	0,0361	7	Adequate
4	2,92	7	Adequate
5	0	7	Adequate
6	0,11	7	Adequate
7	0,08	7	Adequate

Based on Table 1, it can be seen that all the data taken has a value of N' which is smaller than the value of N (N' < N). Hence, all the data is sufficient.

Data Homogeneity Test. The test is used to determine whether or not the time measurement data that was gathered is homogeny. The test used the Upper Control Limit (UCL) and Lower Control Limit (LCL) to determine the data homogeneity by using Equation (2). The weighing of raw materials is used as an example for the calculation of the first work element data uniformity test.

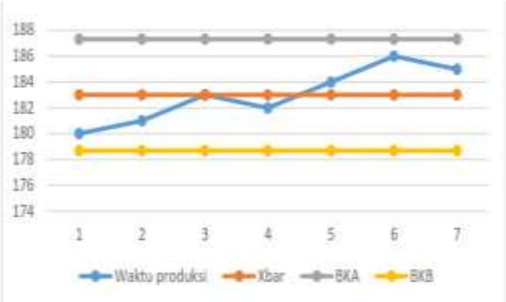

Figure 1. Work Element Control Map 1

Based on the graph in Figure 1, it can be concluded that the measurement data on the work element 1 is uniform. The recapitulation for the data uniformity test on all work elements can be seen in Table 2.

Table 2. Recapitulation of Data Uniformity Test for Each Work Element.

Work Element	X	σ	UCL	LCL	Status
1	183,00	2,16	187,32	178,68	Homogeneous
2	900,00	0,00	900,00	900,00	Homogeneous
3	3623,57	18,64	3660,86	3586,28	Homogeneous
4	328,57	15,20	358,97	298,18	Homogeneous
5	1200,00	0,00	1200,00	1200,00	Homogeneous
6	915,71	8,56	932,83	898,60	Homogeneous
7	1215,43	9,61	1234,64	1196,22	Homogeneous

Calculating Normal Time. Normal time is the time needed by workers to complete a job under normal conditions. To calculate the normal time, it is necessary to know the rating factor for each work station (Trenggonowati & Febriana, 2019), Equation (3) is employed. In this study, the rating factor for each work station is 1 because it is assumed that the workers observed are workers who are quite experienced at work carrying them out without excessive effort, mastering the established work methods and showing sincerity in carrying out their work (Casban & Kusumah, 2016).

Table 3. Recapitulation of Normal Time.

Work Station	Work Element	Normal Time
1	1	183,00
2	2	900,00
	3	3623,57
3	4	328,57
4	5	1200,00
	6	915,71
5	7	1215,43

Calculating Standard Time. Standard time is the time it takes workers to complete a job. To calculate the standard time, it is necessary to know the allowance for each work station (Napitupulu, 2010). There are several factors that determine allowance, namely the energy expended, work attitude, work movement, eye fatigue, ambient temperature conditions, and personal circumstances (Saputra, 2014). Equation (4) is used to determine the standard time and the results are shown in Table 4.

Table 4. Recapitulation of Normal Time and Standard Time (seconds).

Work Station	All	Work Element	Normal Time	Standard Time
1	9%	1	183,00	210,09
2	7%	2	900,00	967,74
	34%	3	3623,57	5490,25
3	34%	4	328,57	497,83
4	17%	5	1200,00	1445,78
	13%	6	915,71	1052,54
5	13%	7	1215,43	1397,04

Calculation of Line Efficiency, Balance Delay, and Smoothness Index on the Actual Production Line. On the actual production line at X Inc., there are 5 work stations with a total of 7 work elements. The actual production line with the standard time for each work element can be seen as follows:

Table 5. Actual Production Line Standard Time.

Work Station	Work Element	Standard Time	Time Per Station	Idle Time	%Idle
1	1	210,09	210,09		
2	2	967,74	967,74		
	3	5490,25	5.988,08		
3	4	497,83			
4	5	1445,78	1445,78	4.542,30	75%
	6	1052,54	2449,58	3538,5	59%
5	7	1397,04			

The standard time for each work element is shown in Table 5. The following computation will be conducted using this standard time. The Line Efficiency, Balance Delay, and Smoothness Index on the real path should then be calculated after knowing the standard time and figuring out the work station cycle time.

1. Line Efficiency
   Line Efficiency is the ratio between the time used and the time available. The higher the track efficiency value, the better the track (Saputra, 2014). The following is the calculation of the line efficiency on the actual line production by using Equation (6).

$$LE = \frac{210.09 + 967{,}74 + 5988{,}08 + 1445{,}78 + 2449{,}58}{(5)(5490{,}25)} 100\% = 40.29\%$$

2. Balance Delay
   Balance Delay is a measure of track inefficiency resulting from actual idle time caused by imperfect allocation between work stations (Eunike et al., 2021). A good production track has a balance delay value close to zero. The following is the calculation of the balance delay on the actual line production by using Equation (7).

$$D = \frac{[(5)(5490{,}25)] - 11061{,}27}{(5)(5490{,}25)} 100\% = 59{,}70\%$$

3. Smoothness Index
   A certain production line's relative smoothness in balancing is measured by a metric called the Smoothness Index (Trenggonowati & Febriana, 2019). A smoothness index value that is near to zero indicates an excellent production line. The calculation is used the Equation (8) to determine the Smoothness index.

$$SI = \sqrt{(5.988{,}08 - 210{,}09)^2 + \cdots + (5.988{,}08 - 1397{,}04)^2} = 9578{,}22$$

Hence, the value of Line Efficiency is 40.29%, Smoothness Index of 9,578.22 and Balance Delay of 59.70% according to the findings of the balance calculation on the actual production line.

Calculation of Line Efficiency, Balance Delay, and Smoothness Index Using the Moodie Young Method. In the first phase, work station grouping is made by making precedence diagrams to form a P matrix (predecessor) and an F matrix (follower). Precedence diagram is a diagram that describes the sequence of work operations and their linkages to other work operations with the aim of facilitating the control and planning of related activities.

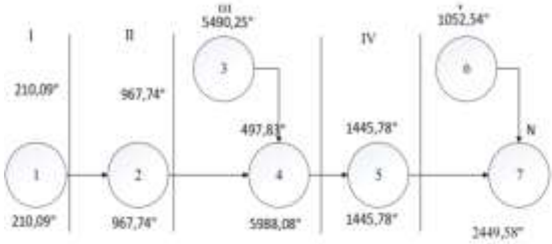

Figure 2. Precedence Diagram

The next step is to make the P matrix and F matrix. As an example, the P matrix shows the relationship of the predecessor work elements, the F matrix shows the relationship of the work elements that follow (Saputra, 2014).

Table 6. P Matrix

Work Element	Predecessor Work Elements	
1	0	
2	0	1
3	2	
4	3	
5	4	
6	5	
7	6	

Table 7. F Matrix

Work Element	Follow Work Elements
1	3
2	3
3	4
4	5
5	6
6	7
7	-

The results of grouping work elements based on what is known so far, such as the P matrix, F matrix, and cycle time (5490.25 seconds). Thus, work elements can be arranged in accordance with the requirements, namely the time for each work station must not have time exceeding the cycle time and the transfer of work elements must not violate the precedence diagram or the P and F matrices.

Table 8. Formation of Workstation (First Phase).

Work Station	Work Element	Standard Time	Time Per Station	Idle Time	%Idle
1	1	210,09	1177,83	-	-
	2	967,74			
2	3	5490,25	5490,25	-	-
3	4	497,83			
	5	1445,78	4393,19	1097,06	25%
	6	1052,54			
	7	1397,04			

A new production line that differs from the real production line is obtained in the first step. On the new track, the outcomes of the first phase of Moodie Young approach shift to just 3 work stations with 7 work elements, as opposed to the original track's 5 work stations and 7 work elements. The precedence diagram on the new path emerging from the first phase of the Moodie Young approach is illustrated in the following figure.

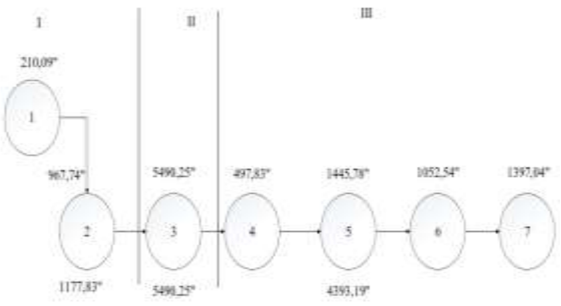

Figure 2. Precedence Diagram of the New Production Line

Then in the second phase which is the result of improvements in the first phase. In this second phase there are several steps, namely as follows.

1. Identify the time of the largest work station and the time of the smallest work station. The sequence of work stations from largest to smallest is work station 2 (5490.25 seconds), work station 3 (4393.19 seconds), work station 1 (1177.83 seconds), determine the "GOAL", which is the difference between the maximum work station minus the minimum work station divided by two.

$$GOAL = \frac{5490{,}25 - 1177{,}83}{2} = 2156{,}21\ seconds$$

2. Identify a work element that is contained in a work station with the maximum time, which has a smaller time than the GOAL, where the work element when moved to the minimum work station does not violate the precedence diagram. Work elements at station 1 can be moved because there are work elements

that have time under GOAL. Likewise, with stations 2 & 3 which have several work elements that have time below the goal but cannot be moved because they violate the precedence diagram. Because in the second phase there is no change from the first phase because all work elements cannot be moved due to violating the conditions, the results of the new production path obtained by the Moodie Young method are as follows.

Table 9. Production Line by Moodie Young Method.

Work Station	Work Element	Standard Time	Time Per Station	Idle Time	%Idle
1	1	210,09	1177,83	-	-
	2	967,74			
2	3	5490,25	5490,25	-	-
3	4	497,83			
	5	1445,78	4393,19	1097,06	25%
	6	1052,54			
	7	1397,04			

As seen in table 9, all work stations on this new path now have times that are closer to the cycle time, resulting in less idle time as compared to the actual production line. Then, the next step is to calculate the Line Efficiency, Balance Delay, and Smoothness Index and then compare it with the results obtained from the actual production line by using Equation (6), (7), and (8). The results for Line Efficiency, Balance Delay, and Smoothness Index are 67.15%, 32.84%, and 4,449.71, respectively, for the computation of the balance on the new production line derived from the Moodie Young approach.

DISCUSSION

There are differences in the level of line efficiency, balance delay, and smoothness index on the actual track and Moodie Young. The following are the differences between the actual path and the Moodie Young method's path on the precedence diagram, as well as their respective levels of Line Efficiency, Balance Delay, and Smooth Index depict in figures and table below.

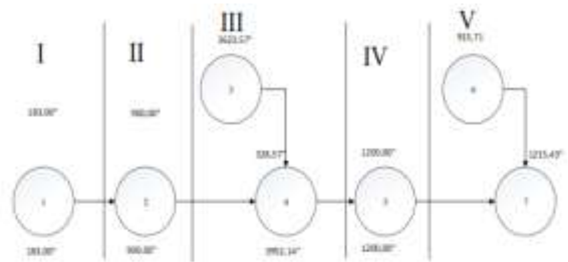

Figure 4. Precedence Diagram of the Early Time Production Line

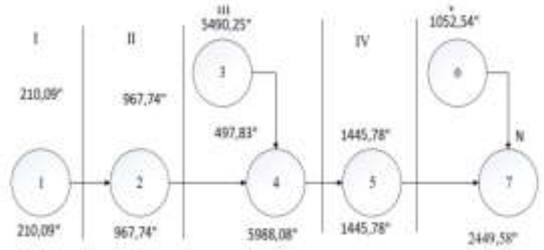

Figure 5. Precedence Diagram of the Actual Time Production Line

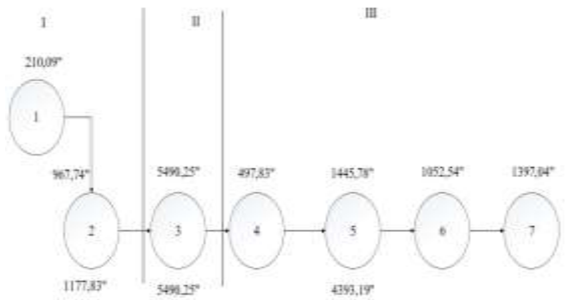

Figure 6. Precedence Diagram of the New Production Line

Table 10. Line Efficiency, Balance Delay, and Smoothness Index on the Actual Line and the Moodie Young Line

	Actual	Young
Line Efficiency	40,29%	67,15%
Balance Delay	59,70%	32,84%
Smooth Index	9.578,22	4.449,71

Line Efficiency is 40.29%, Balancing Delay is 59.70%, and Smooth Index is 9,578.22 on the actual track. The Smooth Index was 4,449.71, the Balance Delay was 32.84%, and the Line Efficiency was 67.15% for the Moodie Young line method. This demonstrates that the Moodie Young production line has a better line balance of production than the actual line at X Inc.

CONCLUSION

The level of line efficiency on the current actual production line is still deemed suboptimal in this study's conclusion based on the research findings. On the Moodie Young method production line, there are 3 work stations with 7 work elements, with a Line Efficiency of 67.15%, a Balance Delay of 32.84%, and a Smoothness Index of 4449.71. There are 5 work stations with 7 work elements, with results for Line Efficiency of 40.29%, Balance Delay of 59.70%, and Smoothness Index of 9578.22.

Declaration by Authors

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