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Improvement of PT XYZ Assembly Line Design Using Helgeson-Birnie Method

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ABSTRACT

PT. XYZ, which is engaged in production and assembly, is experiencing difficulties in the production process of their products. The condition of PT. XYZ's current production line is less effective, it can be seen from the average idle time of 37.56%. The overall average efficiency of PT. XYZ is 62.44%, this condition occurs due to the uneven workload between work stations. In this research, a proposed assembly line track design using the Helgeson-Birnie method will be carried out. The criteria used for comparison of assembly lines is to look at the efficiency of the assembly line and the Smoothness Index (SI) value. The results obtained from the 6 iterations that have been carried out, the results show that the best proposal produces a Smoothness Index value of 11.64 with a trajectory efficiency of 89.35%.

Keywords
Line balancing, Helgeson-Birnie, smoothness index

Introduction

PT. XYZ is a company engaged in the production of woodworking tools. One of the products that is quite highlighted at this time is the production of the jack. The jack production at PT. XYZ is not good enough, this is indicated by the performance of the assembly line conditions before the design which is seen from idle time, free time balance, work station efficiency, track efficiency and Smoothness Index (SI). The observed idle time is 186.17 seconds, this condition is quite long because there are waiting activities at several work stations because the work from the previous station has not been completed. This idle time should be reduced or even eliminated to increase company productivity. The balance of leisure time is 37.56%, meaning that there is idle activity of 37.56% in the track. This can be seen from the time at the largest station minus the accumulated idle time at each work station and compared to the time at the largest station. A good balance of leisure time should be small or close to 0%.

The efficiency of the work station as a whole reaches an average of 62.44%, this condition occurs due to the uneven allocation of workloads. The efficiency of each workstation should be close to 100%. The efficiency of the assembly line means that only 62.44% of the total production time is used and productive. A good track efficiency is 100% or at least close to 100%. The Smoothness Index (SI) value obtained is very large, namely 105.142, a good SI value is a small value and is close to zero.

In this research, a work station design proposal will be carried out at PT XYZ using the Helgeson-Birnie method. The indicator that will be used in designing this work station system is to look at the value of the track efficiency and also the smoothness index on the proposed track compared to the current track conditions.

Literature Review

Line balancing is a series of work stations that are used to make a product which usually consists of a number of work areas handled by one or more operators and tools (Baroto, 2002). Meanwhile, according to Gazperz (2000), line balancing is a process of balancing a number of tasks from the assembly line of a work station to minimize the number of work stations and the total idle time to produce a certain output.

Line balancing problems can be solved by using several methods, including the heuristic method that uses experience, intuition or empirical rules to obtain a better solution than previously achieved solutions. In addition, there is an analytical method, which is a depiction of the real world through mathematical symbols in the form of equations and inequalities. Finally, there is the simulation method, which is a method that mimics the behavior of a system and studies the interactions between its components.

The method used in this research is the Helgeson-Birnie method. This method considers the weight of the longest time in calculating the balance of the assembly line and this method will eliminate the bottleneck because the operation with the longest time is carried out first. In this method, there are several terms that are often used, including:

Precedence Diagram, is a graphical representation of the sequence of work operations and dependence on other work operations. Work elements, are part of the entire assembly process that is carried out. Operation time, is the standard for completing an operation. Cycle time, is the time required to make one unit of product per one work station. Work station, is the assembly line where the assembly process is carried out. Work station efficiency is used to determine the percentage ratio between the total time in the work station and cycle time.

The assembly line performance criteria are seen from idle time, free time balance, work station efficiency, track efficiency and Smoothness Index (SI). Idle time is the time when the operator does not work during working hours, meaning that there is time on the assembly line that does not provide added value. The free time balance shows the percentage of idle time across assemblies. Workstation efficiency is the percentage of use of that work station to make products compared to the longest work station time, this value shows the ratio of workstation time to one another. Track efficiency is the percentage of use of an assembly line, this value shows how efficient the assembly line is. Smoothness Index (SI) is the level of the relative waiting time of an assembly line. The Smoothness Index (SI) value shows the relative smoothness of an assembly line balance. A Smoothness Index (SI) is perfect if the value is zero or it is called the perfect balance.

To determine a better alternative, the step used is to move each work element to the station according to the predecessor job rules, then find the actual station time value. After obtaining the actual time for each station, the criteria for alternatives are sought using the calculation formula:

$$Idle\ Time = n.CT - \sum_{i=1}^{n} ET_i$$

$$Idle\ Time\ Balance = \frac{n.CT - \sum_{i=1}^{n} ET_i}{n.CT}\ x\ 100\%$$

$$Smothness\ Index\ (SI) = \sqrt{\sum_{i=1}^{n} (CT - ET_i)^2}$$

Methodology

The research methodology begins by identifying the problems that exist in the company. After getting the problems that exist in the field of painting and the frequent occurrence of line imbalances, then proceed with a literature study. After collecting data, the next process is to test using the Helgeson-Birnie method.

Helgeson-Birnie method is a method used to balance the trajectory in the production process by knowing in advance what time is in the assembly process with the aim that the production process runs well. The steps taken in this research were to use the Helgeson-Birnie method, which is:

a. Calculate the weight of each work element. The element weight is the time from the start of a job to completion at that workstation.
b. Add up the operation time and the path/node/network that has been formed.
c. Sort the work elements based on the largest to the smallest weight values.
d. Distribute work elements on each work station with the rule that the total time of work elements distributed on the workstation must not exceed the cycle time specified in the previous step.
e. Issue work elements that have been distributed to the work station.
f. Allocation of operations to one of the stations, the total processing time must not exceed the CT (Cycle Time) that has been determined.
g. Repeat the previous steps until all work elements are distributed on the workstation. (Bedworth & Bailey, 1987).

After getting the results of calculations using the Helgeson-Birnie method, the last step is to carry out an analysis based on the results of the calculations that have been obtained.

Results and Discussion

Data and Demand

The data for forecasting demand for each type of product for 12 periods are as shown in Table 1.

Table 1. Demand of product

Period	Product A	Product B	Product C	Period	Product A	Product B	Product C
1	25324.22	9859.52	4965.83	7	27051.31	10127.77	4965.83
2	21537.53	9904.23	4965.83	8	23264.61	10172.48	4965.83
3	22842.77	9948.94	4965.83	9	24569.86	10217.19	4965.83
4	20832.87	9993.65	4965.83	10	22559.96	10261.90	4965.83
5	24097.19	10038.35	4965.83	11	25824.27	10306.60	4965.83
6	26136.67	10083.06	4965.83	12	27863.75	10351.31	4965.83
Average demand per period/month				39396.67			
Total working hours per period (second)				1440000			
Desired cycle time (second)				36.551			
Minimum Number of Workstation				5.218			

PT. XYZ produces three types of jacks with 18 elements of assembly activities, the precedence diagram of the unloading process is shown in Figure 1.

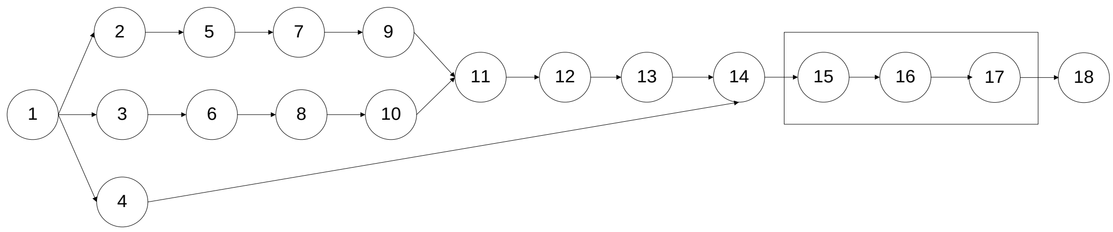

Figure 1. Precedence diagram line production PT. XYZ

Description of activity and standard time for each process element is shown in Table 1.

Table 2. Activity and element time of line production

No.	Activity	Time (s)
1	The jack part preparation process	0.00
2	The process of unifying the lower arm bracket with the lower arm becomes the S9A1 sub assembly	3.35
3	The process of unifying the upper base with the upper arm becomes the S9A2 sub assembly	1.59
4	The process of fusing the bolt shaft and handle bracket with nylon bush into S3A2 sub assembly	1.78
5	The process of assembling the arm pin bracket with the S9A1 sub assembly into the S8A1 sub assembly	27.09
6	The process of unifying the arm pin with S9A2 sub assembly into S8A2 sub assembly	25.02
7	The process of unifying the lower arm bracket with the S8A1 sub assembly becomes the S7 A2 sub assembly	4.91
8	The process of unifying the upper arm with the S8A2 sub assembly into the S7A2 sub assembly	1.80
9	The process of joining the arm pin bracket with the S7A1 sub assembly into the S6A1 sub assembly	27.36

10	The process of unifying pin arm with S7A2 sub assembly into S6A2 sub assembly	16.12
11	The process of assembling S6A1 sub assembly and S6A2 sub assembly into S5A1 sub assembly	3.70
12	The process of unifying the bush shaft with S5A1 sub assembly into S4A1 sub assembly	26.20
13	The process of unifying the nut shaft with S4A1 sub assembly into S3A1 sub assembly	30.49
14	The process of unifying the S3A1 sub assembly with the S3A2 sub assembly into an S2A1 sub assembly	5.21
15	The process of unifying the bush stopper with the S2A1 sub assembly into an S1A1 sub assembly	3.00
16	The process of turning the Bracket Handle	6.05
17	The process of installing and tightening the LM4x15 Bolt	4.88
18	The process of unifying Handle Rod with S1A1 sub assembly into assembly A.	2.17
Total		190.72

The design conditions of the PT. XYZ assembly line before the repair are shown in Table 3.

Table 1. Existing condition of line production

Work Station	Work Element	Cycle Time (CT)	Idle Time	Total Time/Part
1	2,5,7,9	79.00	5	84
2	3,6,8,10	60.69	6.54	67.23
3	11,12,13	58.00	4.5	62.5
4	4,14	12.62	3	15.62
5	15,16,17,18	99.12	7.89	107.01

The initial conditions before the track design were carried out, the production process was carried out using 5 assembly work stations. At work station 1 there are 4 work elements, namely 2,5,7, and 9 with the time produced by the work station is 79 seconds. Workstation 2 consists of 4 work elements, namely 3,6,8, and 10 with the resulting time of 60.69 seconds. Workstation 3 consists of 3 work elements, namely 11, 12, and 13 with a time of 58 seconds. Workstation 4 consists of 2 work elements, namely 4 and 14 with a total time of 12.62 seconds. Workstation 5 consists of 6 work elements, namely 15, 16, 17, and 18 with a total time of 99.12 seconds. The results of these observations indicate that the total cycle time is 99.12 seconds which is the longest time at the work station.

The performance criteria from the observation results of the assembly line conditions before the repair are shown in Table 4. From these observations it was found that the idle time for the assembly line was 186.17 seconds with an efficiency value of 62.44% and a smoothing index value of 105.142.

Table 2. Performance criteria existing line production

Idle Time	186.170
Idle Time Balance	37.56%
Work Station 1 Efficiency	79.70%
Work Station 2 Efficiency	61.23%
Work Station 3 Efficiency	58.51%
Work Station 4 Efficiency	12.73%
Work Station 5 Efficiency	100.00%
Line Efficiency	62.44%
Smoothness index	105.142

In the observations before the design, there is a bottleneck at work station 3 and work station 5. The bottleneck at work station 3 is because in doing their work, the operator's work is a little slow which does not provide normal performance and is unemployed several times. The bottleneck at work station 5 is because the workload allocated to each work station is uneven, so when work at work station 4 is finished, work station 5 cannot continue its new job because it is still working on the previous work. Unemployed activities occur at work station 3 and work station 4. Work station 3 is unemployed because it is waiting for parts of work stations 1 and 2. Work

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station 4 is unemployed because it is waiting for parts of work station 3 and workload at work station 4 is very light. After calculating, the resulting cycle time is 99.12, while the expected is 36.55. The minimum number of work stations is 6 work stations, while in the simulation there are only 5 work stations. Therefore, at least 1 work station must be added in order to improve assembly performance.

Cycle Time Calculation

There are two types of cycle time, namely desired cycle time and actual cycle time. Actual cycle time is the largest station time on an assembly line, while the desired cycle time is the time required to produce one unit of product on the assembly line so that demand is met. Assuming that the working days in one period are 25 working days, where one day has 2 shifts, each of which is 8 working hours, the desired cycle time for the assembly process is:

$$Desired\ Cycle\ Time = \frac{Total\ wokring\ hours\ per\ period}{Demand} = \frac{1440000}{39396{,}67} = 36{,}55\ second$$

Minimum Number of Work Station

By knowing the desired cycle time of a production line, the minimum number of work stations required can be calculated using the following calculations:

$$Minimum\ Number\ of\ WS = \frac{Total\ wokring\ time}{Desired\ Cycle\ Time} = \frac{190{,}72}{36{,}55} = 5{,}22 \approx 6\ WS$$

After calculating using the Helgeson-Birnie method, the optimal results are obtained in the 6th iteration as shown in Table 5.

Table 3. Performance criteria result

Desired Cycle Time	36.551				
Work Station	**Work Element**	**Element Time (ET)**	**Cycle Time (CT)**	**(CT - ET)**	**(CT - ET)2**
1	1	0.00	30.44	0.05	0.003
	2	3.35			
	5	27.09			
2	3	1.59	26.61	3.88	15.043
	6	25.02			
3	7	4.91	22.83	7.66	58.677
	8	1.80			
	10	16.12			
4	9	27.36	27.36	3.13	9.810
5	11	3.70	29.90	0.60	0.356
	12	26.20			
6	13	30.49	30.49	0.00	0.000
7	4	1.78	23.09	7.41	54.838
	14	5.21			
	15	3.00			
	16	6.05			
	17	4.88			
	18	2.17			
Cycle Time	30.49				

The proposed assembly line is to use 7 work stations, where this proposal has a cycle time of 30.49 seconds which is the largest cycle time of all work stations. The results of the design of the PT XYZ assembly line are shown in Figure 2.

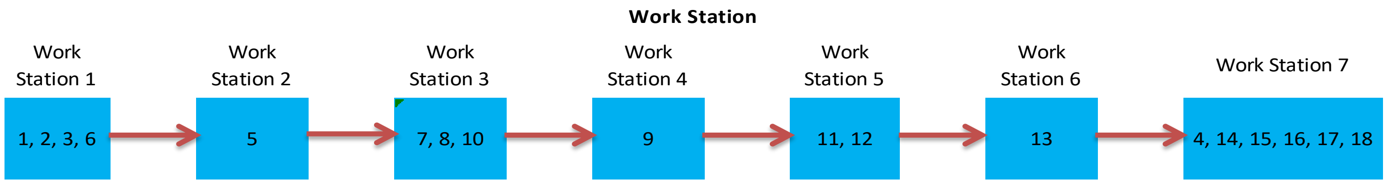

Figure 2. Line production

The proposed assembly line has performance criteria as shown in Table 6.

Table 4. Performance criteria each iteration

Performance Criteria	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6
Idle Time	35.1583	49.0303	33.2602	33.2602	22.7254	22.7254
Idle Time Balance	15.56%	20.88%	14.85%	14.85%	10.65%	10.65%
Work Station 1 Efficiency	88.07%	100%	99.30%	93.66%	99.83%	98.28%
Work Station 2 Efficiency	60.34%	80.73%	100%	100%	87.28%	88.82%
Work Station 3 Efficiency	99.16%	81.55%	85.51%	91.15%	74.88%	74.88%
Work Station 4 Efficiency	96.25%	59.06%	67.47%	67.47%	89.73%	89.73%
Work Station 5 Efficiency	81.19%	78.09%	81.88%	81.88%	98.04%	98.04%
Work Station 6 Efficiency	100%	90.89%	95.30%	95.30%	100%	100%
Work Station 7 Efficiency	66.04%	63.52%	66.60%	66.60%	75.71%	75.71%
Line Efficiency	84.44%	79.12%	85.15%	85.15%	89.35%	89.35%
Smoothness index	18.36	21.95	16.73	16.45	11.78	11.64

After doing 6 iterations of calculations to determine the optimal solution, it is found that the alternative chosen to be the optimal solution in the PT XYZ problem is alternative 6 with a smoothing index value of 11.64.

Conclusion

There are 6 alternatives in cross-assembly design. The six-alternative cross-assembly designs that have been made are then selected the best. The selection of the best alternative is chosen based on the smallest smoothness index value which is closest to 0. In the first alternative it produces a smoothness index value of 18.36 and the last alternative has a smoothness index value of 11.64. Based on the smoothness index value, the alternative chosen is the 6th alternative with a total smoothness index value of 11.64 and the line efficiency of 89.35%. Thus, the alternative can be said to be optimal because it has an efficiency value that is close to 100% and the SI value is the smallest or almost close to 0.

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