Line Balancing Analysis on Finishing Line Dabbing Soap at PT. XYZ

Stephanie Alexandra\textsuperscript{1}, Lina Gozali\textsuperscript{2}

Faculty of Engineering
Industrial Engineering Department
Universitas Tarumanagara
Jakarta, Indonesia

\textsuperscript{1} stephanie.545170017@stu.untar.ac.id
\textsuperscript{2} ligoz@ymail.com

Abstract. PT. XYZ is a company that engaged in cleaners and detergent industry. The unbalance of the production line which is caused by the unequal of work responsibility distribution in each work station that caused the performance of line balance doesn’t work properly. With line balancing in production system will increase the efficiency of production. Line balance method that used to solve these problems is Rank Positional Weight method, Kilbridge-Wester method, Largest Candidates Rules, and Moodie Young method. Beginning of efficiency is 55.73\%, balance delay is 44.27\%, and smoothness index is 3.96 seconds with 5 work stations. By using the Rank Positional Weight method, Kilbridge-Wester method, Largest Candidates Rules, and Moodie Young, obtained efficiency results of 69.66\% and balance delay of 40.34\% with a total of 4 work stations. The results for smoothness index using Rank Positional Weight method and Moodie Young is 2.96 seconds, while Kilbridge-Wester method and Largest Candidates Rules is 2.675 seconds. Therefore, Kilbridge-Wester method and Largest Candidates Rules is the best method because the efficiency increased by 13.93\%, balance delay decreased by 3.93\%, and smoothness index decreased by 1.285 seconds from the beginning line.

Keywords: Line Balancing, Cycle Time, Line Efficiency, Balance Delay, Smoothness Index

1. Introduction

Line balancing plays a very important role in production process in any kind of manufacturing companies. When there is no line balancing in production process, then it can creates the imbalance problems so the waiting time (delay time) and bottleneck can become worst. Imbalance can be made by several factors, namely operator performance, production layout that is not right, and the number of material queues. Line balancing needs to be done to create a balance of the production line so that the production process will run efficiently and improve production efficiency of the company. Line balancing can minimize production wastage with the aim of streamlining mass production, standardization, simplification and specialization.

PT. XYZ is one of the cleaners and detergent manufacturing industries. This research focus on finishing line of dabbing soap product because it’s the most demanded among other cleaners and detergent product from PT. XYZ. To improve the performance of the production of dabbing soap product in PT. XYZ, line balancing should be implemented to their production process so the
workload is equally distributed at each work station. The implementation of line balancing to PT. XYZ’s production process especially at finishing line of dabbing soap product is expected to provide a solution as an alternative to improve the performance of the production line balance by optimizing the balance efficiency, minimizing the balance delay and smoothness index, and optimizing the number of work stations using line balancing method such as Rank Positional Weight method, Kilbridge-Wester method, Largest Candidates Rules, and Moodie Young method.

2. Literature Study
2.1. Line Balancing
According to Gaspersz (2004), line balancing is a balancing the assignment of task elements from an assembly line to a work station to minimize the number of work stations and minimize the idle time at all stations for a certain level of output [1]. The purpose of applying line balancing is to balanced loading at each work station with production speed which are desired, work station load is measured by the time scale, decreasing the amount of work stations, reducing the amount of idle time at each work station and to obtain efficiency and achieve the target of production in accordance with the production plan [2].

There are procedures to apply the line balancing method. The procedures that should be performed include:

a. Make the precedence diagram
   Precedence diagrams illustrate the sequence of work operations from start to finish with the aim of facilitating the control and planning of activities related to it. Precedence diagrams are made with [3]:
   i. Circle symbol (node) with letters or numbers in it; facilitate the identification of an operating process that distinguishes work elements in a production line.
   ii. Arrow; show the sequence and direction of the sequence of operations. Operations that are at the base of the arrow means to precede the work operations that are at the tip of the arrow.
   iii. standard time (Ws); is above the circle symbol (node) which is the time needed to complete each operation.

b. Cycle Time
   Cycle time is the average completion time in an operating process.
   \[ \text{Cycle Time} = \frac{\text{production time}}{\text{Target production}} \]  
   \[ \text{(1)} \]

c. Theoretical Minimum Number of Work Stations
   This calculation shows theoretically the minimum number of work stations needed on a production line.
   \[ \text{Theoretical Minimum} = \frac{\text{Total of task time}}{\text{Cycle time}} \]  
   \[ \text{(2)} \]

d. Choosing the line balancing methods. Each method have different ways to achieve the goal of a balanced production line. These methods have different ways to achieve the goal of a balanced production line.

e. Balance Efficiency
   The calculation of line balancing efficiency is intended as a parameter of the success of the line balancing method.
   \[ \text{BE} = \left( \frac{\text{Total of work station time}}{\text{TM(Cycle Time)}} \right) \times 100\% \]  
   \[ \text{(3)} \]

f. Balance Delay
   Balance delay is the percentage of idle time in a production line because the distribution of operations between stations is uneven.
   \[ \text{Balance Delay} = 100\% - \text{BE} \]  
   \[ \text{(4)} \]

g. Smoothness Index
   Smoothness index is a way to measure the relative idle time of a production line. The minimum value of the smoothness index is zero (perfect balance). If the smoothness index value is getting closer to zero, then the production line is getting more balanced.
\[ SI = \sqrt{\sum (St_{i_{\text{max}}} - St_i)^2} \] 

Where \( St_{\text{max}} \): Largest work station time, and \( St_i \): Time of each work station \((i=1, 2, \ldots, n)\).

2.2. Rank Positional Weight Method
The Rank Positional Weight Method is also known as the Helgeson-Birnie Method. The Rank Positional Weight method prioritizes operations with the longest working time to be grouped into work stations and followed by other operations that have shorter time. According to Bedworth and Bailey (1982) the RPW method has a procedure that can be explained as follows [4].

a. Make a precedence diagram of the production line.
b. Determine the positional weight for each operating element that has the longest completion time from the beginning of the work to the end of the work element that has the lowest completion time.
c. Sort the operating elements by positional weight in the previous step by sorting the operating elements that have the highest positional weight at the top. Continue until the operating elements with the lowest positional weight to each work station.
d. If the work station has excess time, replace the work elements in the work station to the next work station as long as it does not violate the precedence diagram.
e. Repeat steps c and d until all work elements have been placed into the work station.

2.3. Kilbridge-Wester Method
Kilbridge-Wester method also known as the Regional Approach method, the calculation is done by dividing work operations into work station groupings into columns based on precedence diagrams. The steps that must be taken in the Regional Approach method are as follows [5]:

a. Produce the precedence diagram from the production line.
b. Grouping the precedence from left to the right in column area.
c. Grouping elements in many ways to reach the best grouping which has a best or almost the same time with the cycle time.
d. If any elements of work station have no grouping yet and the grouping time is less than cycle time, continue to group with the element in the next precedence.
e. Continue the grouping process until all the elements get the group.

2.4. Largest Candidates Rules Method
The Largest Candidates Rules method prioritizes the largest operating time of a production line which will be grouped into work stations. This method is the simplest and easiest method to understand. Following are the stages of the Largest Candidate Rules method:

a. Make a precedence diagram of the production line.
b. Sort work elements that have the largest completion time to the smallest.
c. Work elements at the first work station are taken from the top sequence (work elements with the largest completion time). Work elements move to the next work station, if the number of work elements has exceeded the cycle time.
d. Repeat step c for the other stations until all work elements have been placed into the work station and the work station time does not exceed the cycle time and meets the precedence sequence diagram requirements.

2.5. Moodie Young Method
The Moodie Young method is suitable when used in companies that have a work operation sequence that starts from one or many separate operations and then reunites in an operating element and ends in one operating element. According to Baroto (2002), the Moodie Young method is divided into two phases (stages) to analyze the balance of a production line [6].

Phase 1:
Phase one is grouping work elements into work stations based on the matrix of relationships between these elements. In phase one a precedence diagram is made for the P matrix and the F matrix which
shows the relationship of the predecessor work element and the work element that follows. After the P and F matrices are made, then the work elements are grouped at the work station in the order in the production line. If there are two work elements to choose from, the work element that has more time is placed first.

Phase 2:
Phase two is revising the work station on the results of phase one. Phase two is carried out to distribute idle time evenly for each station resulting from phase one. Following are the steps in phase two:

a. Identifies the time of the largest work station and the time of the smallest work station.

b. Determine half of the difference between the two goal values (GOAL) with the formula:

\[
GOAL = \frac{(W_{\text{station max}} - W_{\text{station min}})}{2}
\]

c. Specifies a work element (station time) max that is smaller than the GOAL value and which work element is moved to the work station with the minimum time, but does not violate the precedence diagram rules.

d. Move the work element to a work station that has more minimum time if there is a work element at the maximum work station that is smaller than the GOAL value.

e. Perform steps d and e until there are no work elements that can be moved.

3. Research Methodology
Flowchart applied in this research can be seen in Figure 1 below.

![Flowchart](image)

Figure 1. Research Flowchart

4. Analysis Methods
Here are some data of time for each task elements in finishing line of dabbing soap product at PT. XYZ that can be seen in Table 1 below.

| No. | Task Elements                | Cycle Time (sec.) | Normal Time (sec.) | Standard Time (sec.) |
|-----|------------------------------|-------------------|--------------------|----------------------|
| 1   | Labelling cup                | 1.30              | 1.55               | 1.66                 |
| 2   | Adding paper cover to the cup| 1.08              | 1.15               | 1.25                 |
| No. | Task Elements       | Cycle Time (sec.) | Normal Time (sec.) | Standard Time (sec.) |
|-----|---------------------|-------------------|--------------------|----------------------|
| 3   | Filling the cup     | 1.24              | 1.48               | 1.73                 |
| 4   | Closing the cup     | 2.67              | 3.04               | 3.56                 |
| 5   | Packing             | 1.33              | 1.48               | 1.72                 |
|     | **Total**           | **7.63**          | **8.7**            | **9.92**             |

4.1. Line Condition Before Line Balancing
It is known that the finishing line has a work content time (Twc) of 9.92 seconds/cup based on total standard time on Table 1. The cycle time is assumed to use the longest working time on the finishing line which is 3.56 seconds with 5 work stations. The flow of the production process in the finishing line can be seen in Figure 2 below.

![Figure 2. Precedence Diagram of Line Condition Before Line Balancing](image)

Then the balance efficiency, balance delay, and smoothness index can be calculated which can be seen as follows.

\[
\text{Balance Efficiency} = \left(\frac{9.92 \text{ seconds}}{5(3.56)}\right) \times 100\% = 55.73\% \\
\text{Balance Delay} = 100\% - 55.73 = 44.27\% \\
SI = \sqrt{(3.56 - 1.66)^2 + (3.56 - 1.25)^2 + \cdots + (3.56 - 1.72)^2} = 3.96 \text{ seconds}
\]

4.2. Cycle Time
The production capacity of the finishing line of dabbing soap product per day is 250 boxes / shift.

\[
\text{Cycle Time} = \frac{7 \text{ hours/shift} \times 3600 \text{ seconds/hour}}{250 \text{ box/shift} \times 24 \text{ cup/box}} = 4.2 \text{ seconds/cup}
\]

4.3. Theoretical Minimum Number of Work Stations

\[
\text{Theoretical Minimum} = \frac{9.92 \text{ seconds}}{4.2 \text{ seconds/cup}} = 2.361 \approx 3 \text{ work stations}
\]

4.4. Comparison of the Results of Each Methods
The results using Rank Positional Weight method, Kilbridge-Wester method, Largest Candidates Rules, and Moodie Young method can be seen in Figure 3 for the distribution of work stations and Table 2 below.

![Figure 3. Distribution of Work Stations of Each Methods](image)
Table 2. Comparison of the Results of Each Methods

|                        | Before Line Balancing | Rank Positional Weight | Kilbridge-Wester | Largest Candidates Rules | Moodie Young |
|------------------------|-----------------------|------------------------|------------------|--------------------------|--------------|
| Balance Efficiency     | 55.73%                | 69.66%                 | 69.66%           | 69.66%                   | 69.66%       |
| Balance Delay          | 44.27%                | 40.34%                 | 40.34%           | 40.34%                   | 40.34%       |
| Smoothness Index       | 3.96                   | 2.96                   | 2.675            | 2.675                    | 2.96         |
| Longest Cycle Time     | 3.56                   | 3.56                   | 3.56             | 3.56                     | 3.56         |
| Work Station           | 5                      | 4                      | 4                | 4                        | 4            |

The results of calculation using the Rank Positional Weight method, the Kilbridge-Wester method, the Largest Candidates Rules, and Moodie Young, there is a change in the number of stations that decreased from 5 to 4 work stations. The balance efficiency also increased from the initial line of 55.73% to 69.66% and the balance delay decreased from 44.27% to 40.34%. However, the smallest smoothness index is obtained by using the Kilbridge-Wester method and the Largest Candidates Rules of 2,675 seconds. Therefore, it can be concluded that the Kilbridge-Wester and Largest Candidates Rules method has the best results among other methods, so that the method is the best method for this research by increasing the balance efficiency by 13.93%, the balance delay decreases by 3.93%, smoothness index decreased by 1,285 seconds, and subtracted 1 work station from the number of initial line stations.

5. CONCLUSION
Line balancing plays an important role on any kind of production process. Without line balancing, production process can creates the imbalance problems so the waiting time (delay time) and bottleneck can become worst. So, based on the results of calculations and analysis of the research that has been carried out on the finishing line of dabbing soap product at PT. XYZ, for the balance efficiency before line balancing of 55.73%, balance delay of 44.27%, smoothness index of 3.96 seconds, and a total of 5 work stations. Therefore, it is proposed to improve the balance of the finishing line of dabbing soap product using Rank Positional Weight method, Kilbridge-Wester method, Largest Candidates Rules, and Moodie Young. All methods used indicate an increase in performance from the beginning line. However, the Kilbridge-Wester and Largest Candidates Rules method improves performance better than the other two methods. Balance efficiency increased to 69.66%, balance delay decreased to 40.34%, smoothness index decreased to 2,675 seconds and the number of stations decreased from 5 to 4 work stations.

REFERENCES
[1] Gaspersz V.,2004 Production Planning and Inventory Control (Jakarta: Gramedia).
[2] Ghutukade T. S., Sawant S. M., 2013 Use of Ranked Position Weighted Method for Assembly Line Balancing International Journal of Advanced Engineering Research and Studies. 2 PP 01-03.
[3] Dilworth J. B.,2013 Production and Operation Management 5th ed. (Singapore: McGraw-Hill).
[4] Bedworth dan Bailey, Integrated Production And Control System. New York, NY, USA: John Wiley & Sons, 1982.
[5] Gozali L., Ariyanti S., Maria E., 2013. Line Assembly Analysis for R-223 Product by Kilbridge Wester Heuristic Method, Helgeson Birnie Method and Moodie Young Method PT. Mulia Knitting Factory International Conference on Engineering of Tarumanagara (ICET 2013). IE-24 1-11.
[6] T. Baroto, Perencanaan dan Pengendalian Produksi. Jakarta: Ghalia Indonesia, 2002.