Improvement of production layout based on optimum production balancing scale results by using Moodie Young and Comsoal method

Ikhsan Siregar, Tri Ulina Anastasia Sipangkar and Aji Prasetio
Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jalan Almamater Kampus USU, Medan 20155, Indonesia.

Abstract. This research was conducted at a make to order production system company which is engaged in the car body of the vehicle. One of the products produced is dump truck which is one kind of transportation for the transport of goods equipped with hydraulics to facilitate goods’ loading and unloading process. The company has 7 work stations with different cycle times. Companies often experience delays in order delivery. The production process on the production floor has not been done optimally where there is a build up of work in process in some work centres. The build up of work in process (WIP) products is seen in the welding and painting stations. Stacking that occurs on the production line may cause the company to be liable for damages due to delays in product completion. The WIP occurs due to unbalanced paths can be seen from the variance of cycle time of each station is very diverse. The time difference of each work element is due to the allocation of work elements to each work centre unevenly. On the basis of the allocation of uneven work elements, the dump truck assembly line is made. The analysis is done by using Moodie Young and Comsoal method to do the balancing of production line. The result of layout improvement by using systematic layout planning (SLP) method is change the composition of the work centre from 7 into 4 work centre which enables the movement of material to be more effective and efficient so that it can get an efficient and effective production trajectory and can solve existing problems. The result of the track balancing is then used as a guide in constructing a new layout based on the balancing result with the most optimum method.

1. Introduction

Production activities are closely related to the balance of the assembly line. The numbers of element of assembly are grouped into several work stations. In completing the activity of the working element, the available time is determined by the speed of the assembly trajectory. Each work station that is as much as possible should have the same cycle time to avoid idle time between stations. The purpose of this research is to minimize idle time between workstations so that the efficiency of each works station.

Previous research that discussed about line balancing used mathematical model [1] [2]. The purpose of line balancing according to previous research is to design the production line to the maximum, and to seek profit under uncertainty [3]. The problem of the balance of the production path is always there in assembly companies, many researchers conduct research based on case studies, such as in electric factories [4]. In addition, the purpose of line balancing is to minimize, in addition to the number of workstations, the number of high-skilled workers required to complete operations and the number of assembly equipment correctly [5]. Line balancing is structured to achieve efficiency and effectiveness [6] [7]. Even the use of line balancing is used in the aircraft industry [8]. In addition line balancing is also used for balancing validation by simulating labour flexibility [9]. The reason why this
research is done, it is to look at the comparison between the two methods in the line balancing
used and use it in applying layouts that others have not previously seen researchers do before.
Moodie and Young method is applied to all heuristics, then the results are compared based on
the evaluation criteria and Comsoal is the software to calculate it. This research using this
method cause the characteristic problem in the company can solve by using this method. This
research contribution was reduced work centre, and to get more efficiency on time.

2. Research Methods
The type of research used is descriptive research in the form of job and activity analysis.
The form of descriptive research in the form of job and activity analysis is research that aims
to investigate in detail the activities and work of a person or group of people to get
recommendations for various purposes, such as workload balance and efficiency in the use of
time.

The research instrument is a tool used in data collection. Instruments used in this research
are stationery and motion time study to calculate the time of each working element.
Theoretical framework is a conceptual model that shows the logical relationship between the
factors / variables that have been identified important for analyzing the research problem.
This research identifies each element of work. After that, calculate the standard time that will
be used in the repair. Instruments used in the research include stopwatch and pencil and data
collection form. The data collected to conduct this research is in the form of primary data and
secondary data. Primary data consists of data elements - elements of work in the assembly, the
operating process of each element of work and the initial work path of the company.
Secondary data consists of operator number data, machine number data, and effective
working hour data.
The operating time of each working element is calculated from the average yield of 10 times
the measurement. Then calculated normally with the following formula:

\[ \text{Normal Time} = \text{Cycle Time} \times \text{Rating Factor} \]  

(1)

Next is calculated the default time of each working elements by using the following formula:

\[ \text{Standard Time} = \text{Normal Time} \times \frac{100}{100} - \text{allowance} \]  

(2)

This standard time will be used for the next calculation process is to determine the balance of
the trajectory on the transformer assembly. Then calculate the value of balance delay, path
efficiency, and smoothness index of the actual trajectory of the company which is a parameter
to see how far the track is balanced. After that done track balancing by using Moodie Young
and COMSOAL method and then calculated value of balance delay, track efficiency, and
smoothness index of each method. Both methods are compared, than selected methods have
lower balance delay value, higher line efficiency value and lower smoothness index value.

3. Results and Discussion
The imbalance of assembly lines in production activities on the factory floor can be seen
from the unemployment of several work stations, while in other work stations still work in
full. This is due to the time required by a station to complete the work faster than the speed of
a predetermined trajectory.

This company is a company with make to order production system which is engaged in
the car body. The company produces various types of car body. One of the products produced
is a dump truck which is a means of transportation for the transport of goods equipped with
hydraulics to facilitate the process of loading and unloading of goods.
The company has 7 work stations where each work station has different cycle times. The work stations at the company can be seen in Table 1.

**Table 1. Cycle Time of Each Work Station**

| Station | Description     | Time (Minutes) |
|---------|-----------------|----------------|
| I       | Sheet Cutting   | 32             |
| II      | Sheet Forming   | 333            |
| III     | Subframe Assy   | 456            |
| IV      | Welding         | 1253           |
| V       | Painting        | 1108           |
| VI      | Hydraulic       | 824            |
| VII     | Finishing       | 34             |

Table 1 shows that there is a time difference on each work station. As a result of the difference in working time, there is accumulation of work in process product (WIP) at the next station which has fewer working time. The biggest time difference occurs at Station IV (Welding Station) and Station V (Painting Station). At work station VI does not occur accumulation because time used at work station V bigger than time work station VI so no WIP stacking on production floor.

With the problem of stacking on the production floor, it should be noted that the production flow becomes one of the causes of accumulation in the layout of the production flow. Here's the layout of the company's production floor.

![Figure 1. Company’s Layout](image)

Figure 1 shows the production layout of a company that is still not regular and has a distance between stations that make the process of closing the product move becomes longer.

The working element data and the operation time of each element are:
In Table 2, there are 30 work elements that have different working element time. Actual trajectory at company, all working elements are allocated in 7 works centre.

**Initial Trajectory**

The work elements in the initial work centre as well as the time of each work centre can be seen in Table 3.

| Work centre | Working Element | Element Working Time (minutes) | Work Centre Working Time (Minutes) |
|-------------|-----------------|---------------------------------|-----------------------------------|
| I           | 1               | 245                             | 245                               |
|             | 2               | 69                              |                                   |
|             | 3               | 70                              |                                   |
|             | 4               | 81                              |                                   |
| II          | 5               | 29                              | 340                               |
|             | 6               | 32                              |                                   |
|             | 7               | 29                              |                                   |
|             | 8               | 30                              |                                   |
| III         | 9               | 80                              |                                   |
|             | 10              | 57                              |                                   |
|             | 11              | 57                              | 469                               |
|             | 12              | 82                              |                                   |
|             | 13              | 65                              |                                   |
|             | 14              | 128                             |                                   |
| IV          | 15              | 1271                            | 1271                              |
|             | 16              | 153                             |                                   |
|             | 17              | 280                             |                                   |
| V           | 18              | 84                              | 1137                              |
|             | 19              | 83                              |                                   |
|             | 20              | 537                             |                                   |
| VI          | 21              | 41                              | 604                               |

In Table 2, Data of Work Elements in Dump Truck Production Process

| EK  | Time (minutes) | EK  | Time (minutes) |
|-----|----------------|-----|----------------|
| I   | 7              | XVI | 1253           |
| II  | 25             | XVII| 149            |
| III | 68             | XVIII| 273          |
| V   | 79             | XX  | 81             |
| VI  | 28             | XIX | 523            |
| VII | 31             | XXII| 40             |
| VIII| 29             | XXIII| 552           |
| IX  | 29             | XXIV| 74             |
| X   | 78             | XXV | 74             |
| XI  | 56             | XXVI| 39             |
| XII | 55             | XXVII| 28           |
| XIII| 80             | XXVIII| 17          |
| XIV | 63             | XXIX| 19             |
| XV  | 124            | XXX | 15             |
In Table 3. There are 7 trajectories with 30 work elements at the beginning of the work station. Then the calculation of balance delay, line efficiency and smoothness index to see the value of the initial trajectory efficiency.

3.1 Calculating Balance Delay, Line Efficiency and Smoothness Index

a. Calculation of Balance Delay

Calculation of balance delay of a path, using the formula

\[
D = \frac{n \cdot C - \sum Sti}{n \cdot C} \times 100\%
\]

Where on the actual track is known
\n = 7
C = 1271 minutes
\sum Sti = 4336 minutes

Then, balance delay:

\[
D = \frac{7 \times 1271 - 4336}{7 \times 1271} \times 100\% = 51.27\%
\]

b. Line Efficiency

Line efficiency calculation using formula:

\[
E = \frac{\sum S}{n \cdot C} \times 100\%
\]

In the actual trajectory, it is known:
\n = 7
\sum Sti = 4336 minutes
CT = 1271 minutes

Then, line efficiency is :

\[
E = \frac{4336}{7 \times 1271} \times 100\% = 48.74\%
\]

c. Smoothness Index

Smoothness Index calculation using the formula

\[
S = \sqrt{\sum (S_m - S)^2}
\]

Where
Balancing trajectory using Moodie Young Method.

On balancing trajectory by using Moodie Young method obtained balancing result of 4 work centres on production floor. Calculation of Balance Delay, Line Efficiency and Smoothness Index.

a. Balance Delay Calculation

Calculation of balance delay of a path, using the formula

\[ D = \frac{n \cdot C - \sum Sti}{n \cdot C} \times 100\% \]

Where on the actual track is known
\( n = 4 \)
\( C = 1271 \) minutes
\( \sum Sti = 4336 \) minutes
Then, balance delay

\[ D = \frac{4 \times 1271 - 4336}{4 \times 1271} \times 100\% = 14.72\% \]

b. Line Efficiency

Line efficiency calculation using formula:

\[ \varepsilon = \frac{\sum S}{n \cdot C} \times 100\% \]

In the actual trajectory, it is known:
\( n = 4 \)
\( \sum Sti = 4336 \) minutes
\( C_T = 1271 \) minutes
Then, line efficiency

\[ \varepsilon = \frac{4336}{4 \times 1271} \times 100\% = 85.29\% \]

c. Smoothness Index

Smoothness Index calculation using the formula

\[ S = \sqrt{\frac{1}{n} \sum (S - m)^2} \]

Where;
\( SI = \) smoothing index
\( Stimax = \) largest working time
\( Sti = i \) station working time
Then smoothing index;
Based on result of balancing of trajectory balancing result by using method Moodie Young to repair layout at production floor. The results of the improved floor layout of production are as follows:

\[
S = \sqrt{(1271 - 973)^2 + \ldots + (1271 - 955)^2} \\
S = \sqrt{139884} = 374.02
\]

Figure 2 shows the proposed layout based on track balancing result using optimum method that is Moodie Young method. The coordinate point of each department in the proposed layout can be seen in Table 4.

Comparison between existing and proposed are on proposed layout there is 4 work centre, the existing is 7 work centre.
| No | Work Centre Area | Coordinate Point |
|----|------------------|------------------|
|    |                  | X (m)            | Y (m)            |
| 1  | Work Centre 1    | 12,5             | 31               |
| 2  | Work Centre 2    | 12,5             | 52               |
| 3  | Work Centre 3    | 28,5             | 42               |
| 4  | Work Centre 4    | 27,5             | 22,5             |

4. Conclusion
Based on the results of data processing and analysis that has been done can be taken several conclusions as follows:

A. The actual number of work centres is 7 work stations with balance delay 51.27%, line efficiency 48.74% and smoothing index 2006.85.
B. Proposals using Moodie Young obtained work centre reduction into 4 work centres with a balance delay of 14.72%, line efficiency 85.29% and smoothing index 374.02.
C. Selected improvements using the Moodie Young method due to providing better results in efficiency and balance delay.
D. The result of layout improvement by using systematic layout planning (SLP) method is change the composition of the work centre from 7 into 4 work centre which enables the movement of material to be more effective and efficient.

References
[1] Pape, T., 2015, Heuristics and lower bounds for the simple assembly line balancing problem type 1: Overview, computational tests and improvements, European Journal of Operational Research 240, pp. 32–42.
[2] Jonnalagedda, V., 2014, Application of Simple Genetic Algorithm to U-Shaped Assembly Line Balancing Problem of Type II, Proceedings of the 19th World Congress, The International Federation of Automatic Control, Cape Town, South Africa. pp. 24-29.
[3] Bentaha, M., L., 2014, Disassembly Line Balancing and Sequencing under Uncertainty, 21st CIRP Conference on Life Cycle Engineering., Procedia CIRP 15, pp. 239 – 244.
[4] Lam, N., T., 2016, Lean line balancing for an electronics assembly line, 13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use, Procedia CIRP 40, pp. 437 – 442.
[5] Mura, M. D., 2016, Worker skills and equipment optimization in assembly line balancing by a genetic approach, 6th CIRP Conference on Assembly Technologies and Systems (CATS), Procedia CIRP 44, pp.102 – 107.
[6] Altekin, F., T., A Piecewise Linear Model for Stochastic Disassembly Line Balancing, IFAC-Papers On Line 49-12, pp. 932–937.
[7] Oesterle, J., 2016, Hybrid multi-objective optimization method for solving simultaneously the line balancing, equipment and buffer sizing problems for hybrid assembly systems, 49th CIRP Conference on Manufacturing System.
[8] Borreguero, 2015, T., Enhanced Assembly Line Balancing and Scheduling Methodology for the Aeronautical Industry, The Manufacturing Engineering Society International Conference, MESIS 2015, Procedia Engineering 132, pp. 990 – 997.
[9] Pröpsker, M., 2015, Validation of Line Balancing by Simulation of Workforce Flexibility, 9th CIRP Conference on Intelligent Computation in Manufacturing Engineering, Procedia CIRP 33, pp. 93 – 98.