Production layout improvement by using line balancing and Systematic Layout Planning (SLP) at PT. XYZ

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Abstract. PT. XYZ is a wood processing company which produce semi-finished wood with production system is make to order. In the production process, it can be seen that the production line is not balanced. The imbalance of the production line is caused by the difference in cycle time between work stations. In addition, there are other issues, namely the existence of material flow pattern is irregular so it resulted in the backtracking and displacement distance away. This study aimed to obtain the allocation of work elements to specific work stations and propose an improvement of the production layout based on the result of improvements in the line balancing. The method used in the balancing is Ranked Positional Weight (RPW) or also known as Helgeson Birnie method. While the methods used in the improvement of the layout is the method of Systematic Layout Planning (SLP). By using Ranked Positional Weight (RPW) obtained increase in line efficiency becomes 84.86% and decreased balance delay becomes 15.14%. Repairing the layout using the method of Systematic Layout Planning (SLP) also give good results with a reduction in path length becomes 133.82 meters from 213.09 meters previously or a decrease of 37.2%.

1. Introduction

Due to the continuing needs of new industries around the world the planning and regulation of the production process has always been a concern to avoid accidental releases (spills) that can cause public and environmental damage [1]. The design of the plant layout has become the basis of current industrial plants that can affect the efficiency of work. It is necessary to plant and position employees, materials, machinery, equipment, and other manufacturing support and facilities to create the most effective plant layout [2]. However, none of the methodologies can be repeatedly applied to all plant layouts so they turn into the most efficient plant layout. In this sense, making plant layouts is more an art than a science [3].

Line balancing problems are found in various industries. It is categorized into various versions depending on the product timing information in each station and the number of products. Pathway balancing is a powerful managerial tool used to improve productivity of the production system [4]. Line Balancing consists of assigning tasks to each work station, while optimizing one or more destinations without breaking the boundaries. Line balancing is used to achieve the same level of production at each station [5].

Systematic layout planning (SLP) is used to improve spatial distances between facilities (machines and work stations) and also improve the flow of material at a plant. With the SLP is expected material handling costs are reduced significantly, workers move faster and overall productivity increases [6]. In addition the systematic layout planning method (SLP) has also been done in a steel company in Mumbai, India. Research is done for improved productivity and better layout planning. The new factory layout is designed and then compared to the current
layout. The SLP method shows that the new plant layout significantly decreases the material flow distance from the preservation process to the packing [7].

The layout of the plant was carried out in accordance with the systematic steps of plant layout design Yujie et al. Studying a common field using SLP’s that best layout shows a good workflow and practical significance [8]. The industry layout planning is applied to systematic layout planning (SLP) which shows step-by-step planting of the input data and evaluation activities of plant layout. This method provides a new plant layout that improves the process of flowing through the plants, and helps increase the space in the industry [9]. Manufacturing systems that produce many components and functions in highly unstable environments are increasingly challenged to meet consistently high operating levels, efficiency and flexibility [10]. The benefits of a manufacturing system depend on the main factors of designing the engine cell and its parts, setup time and method of operation. The manufacturing system becomes a failure when both of these factors are not used correctly [11]. Various techniques developed for assembly line balance problems have proven useful in various assembly industries such as manufacturing, automobiles, consumer electronics, and others. In traditional straight-line ALBPs, a limited set of tasks for the assembly line are assigned including the associated processing time and the prior relation that determines the permissible sequence of tasks. The goal is to assign a series of tasks to successive workstations to meet specific production requirements, in which the number of workstations required is minimized [12]. The use of tools, materials, and workings is considered to meet the quality requirements if all the requirements specified in the criteria and specifications are met. Methods are crucial in implementing a construction project because the right implementation method can provide project quality from a financial or time perspective. One construction technology that offers several advantages for easy implementation and economics is precast technology [13].

The layout of PL facilities is not only a matter of cost reduction, but also contributes greatly to the efficiency of the PL process. However, the optimization of the PL facility layout has always been neglected in recent decades [14]. The layout is the procedure of setting up the plant facilities to support the smoothness of the production process. Setting by utilizing the existing area to place the engine and supporting production facilities that impact on the smooth movement of material. This is set and machine department. In addition to this arrangement, the selection of one type of facility layout is also influenced by production volume and product variation [15]. The factory layout involves setting and selecting machines, material handling devices, material handling lines, resulting in reduced time and costs. Handling layout issues aims to find spatially related units such as departments and machines [16].

PT. XYZ is one of the wood stem manufacturing companies processing into semi-finished wood material. The problem in the company is that there is a considerable difference in cycle time, resulting in different capacity at each work center shown in Table 1.

| Work Center | Process          | Capacity (/days) |
|-------------|------------------|------------------|
| I           | Reaping Process  | 566 unit         |
| II          | Cutting Process  | 677 unit         |
| III         | Gluing Process   | 314 unit         |
| IV          | Assembling Process | 518 unit     |
| V           | Finishing Process| 251 unit         |
| VI          | Preparation Process | 297 unit     |
| VII         | Packaging        | 316 batch        |

In Table 1 above, there is a difference in capacity at each work center. The average demand per month is 264 units of wood / day. As a result, there is a build up of material at the next work
center which has a smaller capacity. In the table above shows that there is accumulation in work center V as much as 12 units / day.

Besides the buildup problem, there are also problems in the production flow. Layout of factory production section of PT. XYZ can be seen in Figure 1.

![Figure 1. PT. XYZ Layout](image)

In Figure 1 it can be seen that there is an unfavorable flow of material seen in the presence of irregular material flow patterns resulting in the intersection of the trajectory between the cutting station to the dive station and the merging station to the finishing station. This intersection causes the distance of the production line to be longer that is 213.09 meters.

2. Research Methods
This research was conducted at PT. XYZ in May 2016 until July 2016. The type of research conducted is descriptive research in the form of job and activity analysis [17]. The object of research is the trajectory of production in the process of wood bar production as raw material for making furniture. The general objective of the research is to obtain a design of the production floor layout by considering improvements in track balance.

The dependent variable in this research is the production floor layout with the optimum balance of production trajectory. Independent variables used in this study, namely:

a. Cycle Time is the time it takes the operator to complete his work.

b. Rating factor is the adjustment factor given by the researcher on the operational reasonableness of the operator.

c. Allowance is a factor of adjustment given by the researcher to the existence of a number of non-work needs that occur during the work.

d. The area of production is the data area of each operation is used to know the area used by each operation to be used as a block design in facilitating the preparation of the layout of the production floor.

Data collection is done by measuring cycle time at each work station by using stopwatch time study method [18]. In addition to cycle time collection, production floor data collection is also conducted.

Data processing is done in three stages. Namely processing time cycle data, processing track balance and processing of production floor production.
The analysis is done by comparing the balance delay, smoothness index, line efficiency and production line distance between actual trajectory with the proposed trajectory.

2.1. Processing time cycle data

The result of time cycle measurement will be uniform test where each data obtained must be below Upper Control Limit (BKA) and above Lower Boundary Control (BKB). Having obtained that the data is uniform, then tested sufficiency with the formula:

\[
N' = \left( \frac{k}{N} \frac{\sum X - (\sum X)^2}{\sum X} \right)^2
\]

(1)

Where:

- \( N' \): Number of observations
- \( : \): Measurement data
- \( s \): Level of thoroughness
- \( k \): Level of confidence

If the data obtained is uniform and sufficient, then the normal time calculated and then the standard time. The normal time formula follows:

\[
\text{Normal time} = \text{Cycle time} \times \text{Rating factor}
\]

(2)

While the standard time formula is as follows:

\[
\text{Standard time} = W \times \text{Normal x (1 + Allowance)}
\]

(3)

2.2. Line Balancing Processing

The positioning weight method is the earliest developed heuristic. This method was developed by W. B. Helgeson and D.P. Birnie (Nasution, 2008) [19].

2.3. Creation Layout Processing

After obtaining the allocation of work elements at the work station, then arranged the production floor using systematic layout planning method (SLP).

2.4. Problem Solving Analysis Method

Having obtained the allocation of proposed layout with a more balanced path, then compared the parameters balance delay, smoothness index, line efficiency and long distance of production floor. The formula for finding balance delay (BD) and smoothness index (SI) are:

\[
BD = \frac{\sum_i (CT\times N_i) \times 100%}{CT\times N} \]

(5)

\[
SI = \sum_{i=1}^{K} (WSK_{max} - WSK_i) \]

(6)

The calculation of the length of the production path is done by using the rectilinear distance method, by the formula:

\[
d_{ij} = |x-a| + |y-b|
\]

(7)

3. Results And Discussion

3.1. Results Weighted with Line Balancing
The use of the Positional Weight (RPW) method of allocation of work elements into the work center can be seen in Table 2.

| Work Station | Work Element | Work Time | Total Time |
|--------------|--------------|-----------|------------|
| 1            | 1            | 6.55      | 81.63      |
|              | 2            | 37.9      |            |
|              | 3            | 32.01     |            |
|              | 4            | 5.17      |            |
| 2            | 5            | 22.6      | 80.04      |
|              | 6            | 57.44     |            |
| 3            | 7            | 7.74      |            |
|              | 8            | 29.72     | 48.62      |
|              | 9            | 11.16     |            |
| 4            | 10           | 93.29     | 93.29      |
|              | 11           | 7.05      |            |
| 5            | 12           | 67.39     | 91.67      |
|              | 13           | 17.23     |            |
| 6            | 14           | 47.02     | 79.71      |
|              | 15           | 32.69     |            |

In Table 2 it can be seen that the number of work center proposals is as much as 6 work centers with each work element already allocated.

3.2. Line Balancing Performance Comparison

The purpose of line balancing is to maximize line efficiency and minimize work center, balance delay and smoothness index. Comparison of track criteria of actual conditions and proposals can be seen in Table 3.

| Reference Parameters          | Condition |   |
|------------------------------|-----------|---|
|                              | Actual    | Revision |
| Number of work station (unit)| 7         | 6     |
| Balance Delay (%)            | 27.26     | 15.14  |
| Smoothness Index              | 89.52     | 49.93  |
| Line Efficiency (%)           | 72.73     | 84.86  |

In Table 3 it can be seen that the decrease in the number of work centers from the previous 7 work centers to 6 indicates if this revision is applied in the factory then the path with 6 work stations is more efficient and the delay time or idle is smaller. The value of the line efficiency at the proposed condition is 84.86% from the previous condition that is 72.73% which means the decrease of material accumulation between the work stations. Balance delay from the previous 27.26% to 15.14%, which means reduced idle time caused by poor allocation between the work stations and the smoothness index to 49.93 from the previous 89.52 which means the relative waiting time decrease from a production line. So from the results of the comparison, it can be said the balance of the proposed trajectory better than the actual trajectory.
3.3. Changes in Production Flow Patterns

After the redesigned layout, then no longer found back tracking and also obtained material flow changes. Prior to the redesign, the flow of material used is irregular, as can be seen from the irregularity of material displacement on the production floor. After the design, we get a proposed layout that can be seen in Figure 2. In the figure, it can be seen that after the redesign, the material flow with U shape is formed where the raw material and finished product are in adjacent position on the production floor.

3.4. Comparison of Initial Layout and Proposed Layout

The distance between machines in the production section is not well organized where there is a great distance between machines, the absence of standard flow patterns and the occurrence of back tracking, so this causes the movement of materials must travel a long distance and result in longer production time. The initial track length is 213.09 meters. After the redesigned layout by using systematic layout planning (SLP) method obtained the length of the production path to 133.82 meters or decreased by 79.27 meters. The calculation of the total correction of material displacement moment is as follows.

\[
\text{Correction} = \frac{213.09 - 133.82}{213.09} \times 100\%
\]

\[
\text{Correction} = 37.2\%.
\]

4. Conclusions

The conclusions obtained from the research results are as follows:

a. The use of Positional Weight (RPW) Methods to improve path balance, new path with reduction of work station to 6 stations with balance delay of 15.14%, line efficiency of 84.86% and smoothness index of 49.93.

b. The use of Systematic Layout Planning (SLP) method in layout improvement, got new layout with previously irregular flow pattern into U-shape flow pattern.

c. The initial production trajectory has 7 work stations with balance delay of 27.26%, 72.73% line efficiency and 89.52 smoothness index. After the track balancing, the number of stations obtained 6 stations with balance delay of 15.14%, line efficiency of 84.86% and the smoothness index of 49.93.
d. The result of layout improvement using systematic layout planning (SLP) method was found to change the flow pattern of the material and also the reduction of track production length from 213.09 meter to 133.82 meter, or decrease the trajectory length 79.27 meter or 37.2%.

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