Analysis of production line balancing using genetic algorithms

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Abstract. XYZ company has a problem on the production line that is the build up of work stations and bottlenecks that indicate an imbalance. The aim is to solve the problem of balancing the production line at the company. The production line using the Genetic Algorithm method is done by determining objective parameters and functions, making the encoding of the work station, determining the initial initialization according to the actual production path, then doing iteration with selection, crossover, and mutation to form a new population, and ending with the termination of the algorithm. The results of the actual production line obtained are the number of work stations as many as 8 work stations and with the largest cycle time of 2213 seconds. The genetic algorithm production trajectory is obtained after achieving the maximum objective function value or until the maximum iteration limit is reached and consists of 7 work stations with the largest cycle time of 2203 seconds, and has a higher efficiency value thereby minimizing idle time, having a higher value of balance delay low so that it shows a decrease in waiting time and a lower value of the smoothing index compared to the actual production line where the production line is more balanced, meaning that the division of work elements is quite evenly distributed on the assembly line.

1. Introduction

A good production system that has a balance in the production path used because in the production activities there is a process flow from each department requires different time [1]. XYZ is a private company engaged in the manufacturing of wood products based on [2] the Finger Joint Laminated Board (FJLB). In this company, there was a build-up problem on the production line where there were stations experiencing bottlenecks because it took quite a long time. Production path images can be seen in Figure 1.

![Production Line Path](image)

**Figure 1.** Actual work path.

The average daily data stacking Work in Process (WIP) at the problematic station can be seen in Table 1.1.

| Work Station | WIP Amount / Day (Unit / day) |
|--------------|-------------------------------|
| III          | 10                             |
| V            | 20                             |

Based on Table 1.1, it can be seen that work station III has a WIP of 10 units per day and at work station V has WIP of 20 units per day. The existence of bottlenecks at these work stations shows that the allocation of labor elements on the production line is still not balanced.
2. Methods
In this study, observations were made on the production floor of XYZ. The method used in data collection is Observation and Documentation. Researchers measure time continuously (Continuous Timing) using a stopwatch. In this study, the authors use the tile algorithm as a method of solving existing problems. The stages of genetic algorithms are as follows [3]:
1. Determine objective parameters and functions of genetic algorithms. The parameters used in this study are: (popsize; pc; pm) = (3; 0.98; 0.01), with the objective function to be achieved namely to maximize the efficiency of the path.
2. Make encoding for Work Center and work elements for each work center.
3. Conduct initialisation by generating Initial Initialization using Ranking Positional Weight method to produce the first chromosome (Chromosome A), with 2 added chromosomes randomized. The results of this initial initialization will be the initial population of genetic algorithms.
4. Iterates in the following order:
   • Selection
   At this stage, selection is carried out using the Roulette Wheel. This method allows a chromosome with a high fitness value to be the first chromosome selected.
   • Crossover
   At this stage a crossover of the existing chromosomes will be carried out. If the chromosome has a smaller random number than the probability of a crossover in the initial parameters, the chromosome will be crossovered.
   • Mutation
   The mutase stage is carried out only on the part of the gene that allows mutations to be carried out. Formation of new population in accordance with the results of iteration. Stopping criteria check, where repetition is carried out until the stopping criteria is fulfilled. Stopping Criteria in this study is if there is no significant change in cycle time after several repetitions and / or after the maximum iteration is reached.

3. Result and discussion
The data obtained is then tested using a data sufficiency test and data uniformity test. The results obtained are sufficient data and uniform data, then the normal time and standard time are calculated. The next step is obtained the actual state of the production line using Ranked Positional Weight method.

3.1. Actual state
The actual Production line is obtained using the Ranking Positional Weight method, can be seen in Figure 2.

On this production line, performance measurement measures such as balance delay, efficiency and smoothing index are calculated. The equation for balance delay, efficiency and smoothing index are as mentioned below:

\[
\text{Balance delay} = \frac{n \times \sum Si}{n \times Sm} \times 100\% \quad (1)
\]
"Efficiency" = \frac{\sum_{i=1}^{n} S_i}{n \cdot S_m} \times 100\% \quad (2)

Smoothing index = \sqrt{\sum_{i=1}^{n} (S_m - S_i)^2} \quad (3)

Where:
- \( n \) = Amount of work center
- \( sm \) = cycle time
- \( S_i \) = cycle time on work center \( i \)

The production line is in the initial condition with a cycle time of 2304 seconds and there are 8 work stations. The known value of balance delay is 31.61%, efficiency is 68.39% and smoothing index is 2314.64.

3.2. Proposal conditions

Genetic algorithm trajectory obtained using the help of MatLab software with a total iteration of 600 iterations, can be seen in Figure 3.

| WC I | WC II | WC III |
|------|-------|--------|
| 1-2-3-4-5-6-7-8 | 9-10-11-12-13-14-15-16 | 17-18-19-20-21-22-23-24 |
| 25-26-27-28-29-30-31-32 | 33-34-35-36-37 | WC VII WC VI WC V WC IV |

Figure 3. Genetic algorithm work path.

Genetic algorithm production line with a cycle time of 2304 seconds and there are 7 work stations. The known value of balance delay is 21.84%, efficiency is 78.16% and smoothing index is 1738.43. In table 1 it can be seen the comparison of performance measures of genetic algorithm production line with actual production line.

| Production Line | WC | Efficiency (%) | Balance Delay (%) | Smoothness Index |
|-----------------|----|----------------|-------------------|-----------------|
| Actual          | 8  | 68.39          | 31.61             | 2314.64         |
| Genetic Algorithm| 7  | 78.16          | 21.84             | 1738.43         |

4. Conclusions

There are several conclusions that can be drawn based on the results of this study as follows:

The production process at Sumber Karindo Sakti consists of 37 work elements that comprise 8 workstations. Also on the actual track there is a buildup at work station III and work station V, causing bottlenecks.

Production trajectories obtained using genetic algorithms give results, namely trajectories consisting of 7 work stations. Besides that, the biggest cycle time is 36.7200 seconds, and fitness value is 0.7816. This production line was obtained after the 600th iteration was carried out.

There are some differences between the actual trajectory and the genetic algorithm trajectory [4]. Performance measures on the actual trajectory have differences with performance measures on the genetic algorithm trajectory. Calculation of performance measures shows the results on the actual trajectory has a balance delay value of 31.61%, efficiency of 68.39% and smoothing index of 2314.64. While the genetic algorithm trajectory has a value of balance delay of 21.84%, efficiency of 78.16% and smoothing index of 1738.43. Based on the data above, it can be concluded that the genetic algorithm trajectory is better than the actual trajectory [5].
References
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