Assembly Line Balancing Using Genetic Algorithm Method to Minimize Number of Working Stations: A Case Study in Car Manufacturing

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Abstract. In this competitive era, there are no more manufacturing organizations that want to produce products in large volumes with low variations. The company is now shifting toward the idea of producing more variations that are of interest to consumers. Increased demand and production targets cannot be avoided; however, the increase must be adjusted to the worker’s resources according to their function. If it is not balanced, it will cause a bottleneck on the production flow caused by the operating time at a workstation exceeding the takt time. Then we need to balance the assembly line to get optimum and efficient results. Assembly line balancing (ALB) is used to flatten workload on all processes in a cell or value stream to eliminate bottlenecks and excess capacity, with a limitation of slowing down process time and excess capacity. The completion of this case study uses a combination of Priority Rule-Based/heuristic methods and Genetic Algorithm methods.

1. Introduction

In the competitive era, there are no more manufacturing organizations that want to produce products in large volumes with low variations. Companies are now shifting towards the idea of producing more variations that are of interest to consumers [1]. PT XYZ is a car automotive company from Germany. In Indonesia, PT XYZ produces six types of cars, namely types C, E, GLC, GLE, GLS, and S. The assembly system in the type of car is divided into two production lines, the first line produces type C, E, and GLC. The cars that are produced on line 2 are GLE, GLS, and S-Class. In this case study, the company stopped producing GLE and GLS types for the next few years. This stoppage aims to prepare for the launch of the production of the latest models of the two types. As a result of the cessation of production, an increase in demand, and production targets for the S-class type. Thus, PT XYZ strives to meet production targets on line 2 by making an assembly plant analysis that contains targets and product realization every month for 2018. Figure 1 shows an increase in demand and production targets on the production line 2.
Figure 2 shows that the production target is not achieved in several months, namely June, August, September, October, and December 2018. Based on these data, an analysis of the time distribution of each work station on the mechanical line 2 assembly line is used. Know work stations whose operating time exceeds the takt-time so as to result in bottlenecks on the assembly line. There was a bottleneck of 2 product units at work station 12 and work station 14 (Table 1). This condition resulted in idle at work station 13 and idle at work station 15 to work station 19. This shows that there is an imbalance of the production line on line 2. Balance of production line is key for organizational productivity in terms of reducing the number of work stations and certain production volumes [2].

| Work Station | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|--------------|----|----|----|----|----|----|----|----|
| Bottleneck (unit) | 2  | 0  | 2  | 0  | 0  | 0  | 0  | 0  |

A bottleneck occurs because the processing time at work station 12 and work station 14 exceeds the existing takt-time. At other workstations, the work time is still below the takt-time so that it is still possible to balance the allocation of processes (tasks) between workstations.

This research was conducted to improve the performance of assembly lines at work stations 12 to work stations 19 on assembly line 2 (mechanical line 2) by minimizing the number of work stations so that PT XYZ can allocate the functions of work stations resulting from line balancing for the needs of repair stations (rectification).

2. Methodology

2.1. Assembly Line

Forecast is an activity that is often used to predict the number of requests in a certain period using historical data [3]. Forecasting the number of requests in assembly and manufacturing depends on the number of product units to be produced in each period. Some requirements are used to fulfill the demand to predict the demand, so that it can help the right production planner, namely the presence of workers, equipment and other resources [4].

In the assembly line system, there are three types of production namely single product line, family of product lines and multiple product lines. Each assembly line production system has its characteristics and criteria, so that the selection and use need to be adapted to the state of the company. Single-line models are used to produce only one product. If dynamic phenomena are ignored, the workload of all stations remains constant over time, preferably using this assembly line model. Mixed-model line is a family of products that have features in the type (variant). Assembly Line Balancing (ALB)

Assembly line balancing (ALB) is leveling the workload on all processes in a cell or value stream to eliminate bottlenecks and excess capacity. With the limitation of slowing down processing time and
results if waiting for downstream from operations and excess capacity causes waiting and absorption of fixed costs [5]. In balancing the assembly line there are several steps to solving the problem.

2.2. Priority Rules-Based Methods (PRBMs)

Priority Rules-Based Methods (PRBMs) are a heuristic method used for specific problems (simple assembly line problems) to build good solutions in a relatively short time [6]. This method can be used singly or can also be used by integrating into other problem-solving procedures, such as branch and bound, dynamic programming, genetic algorithm (GA).

2.3. Genetic Algorithm (GA)

Genetic Algorithm (GA) is a stochastic global search method that mimics the natural biological evolutionary metaphors of populations. GA operates in a population of potential solutions that apply the principle of survival of the fittest solution. At each generation, a new set of potential solutions is created by the process of selecting individuals according to their fitness problem domain and manipulating it like natural genetics [7]. This process leads to the evolution of individual populations that are more suitable and superior in their environment than previous individuals, as in natural adaptation. This technique is very useful for complex optimization problems with a large number of parameters and then makes global analytic solutions difficult to obtain. The main operations of GA are initialization, fitness evaluation, individual selection, mutation, and crossover. The Genetic Algorithm gradually selects several parent populations and produces several iterative children until enough children have been created.

2.4. Conceptual Model

In the conceptual model of this research, the input data of this study are cycle time data, the number of work stations, product workflow, and assembly output. The method used for the initial population in balancing the assembly line is the Priority Rule. This method is used to make the initial population of work elements and work stations in accordance with the workings of the genetic algorithm method. After that, an analysis of the ratio of idle time, the efficiency of the track, smoothness index, and output level of the assembly are conducted. The method is chosen to get the optimal proposed assembly path design.

![Figure 3. Conceptual Model](image)

3. Discussion and Result

The case study used to conduct this research has an assembly area consisting of an assembly area outside the car (trimming line) and an assembly area for mechanical components (mechanical line). The assembly work system in the mechanical line 2 area is the station waist, i.e. each workstation has a different operator. Production line balance is the key to organizational productivity in terms of reducing the number of workstations and certain production volumes [2]. To increase the productivity
of the mechanical line production line, it is necessary to develop a production line. At first, to improve line balancing performance, we need to determine some input data:
1. Demand, assumed demand is deterministic and constant, 10 units
2. Existing work element
3. Time of existing work elements
4. Working time
5. Precedence diagram
6. Existing performance index

3.1. Assembly Line Balance Using Rule-Based Priority
After the results of the actual assembly line performance index are known, at this stage an assembly line balance calculation will be performed using the Priority Rule method to get a better Mechanical Line 2 assembly line performance index result. Following are the steps to balance the assembly line using the Priority Rule-Rule method.
1. Scheduleable Operation
   In using the Priority Rule method, the first step that must be done is to make a list of operations (Scheduleable Operations). In carrying out a list of operations, a table contains work elements (K), operating time (O) and work station (WS), iteration (i), maximum duration of work station time, idle time, and maximum operating time. In entering operation data, it is important to consider choosing operations that do not have operations that need to be done before (predecessor).
2. Candidate Operation
   After having an operation scheduling list, select the operation that has the highest time and does not exceed the work station time. The operation was chosen as a candidate for the proposed operation to be made. The next selected candidate needs to pay attention to the accumulation of the amount of operating time with the work station time, if it exceeds then the candidate is the operating candidate at the next station.
3. Select Candidate
   In the previous stage the selected work element is the work element that has the highest time and does not exceed the work station time. The selected work element is a predecessor for other work elements, if the predecessor work element is selected then the work element associated with the selected work element will enter as a new candidate and ready to be chosen as the next operating candidate.

3.2. Assembly Line Balance Using Genetic Algorithm (GA)
3.2.1. Forming Parameters
   We use model from previous researcher [8] and MATLAB Software to solve assembly line balancing using genetic algorithms. In the application of this method consists of several forming parameters for the calculation of the balance of the assembly line as follows:
1. Population Size
   We use population size as initials consists of 5 different chromosomes.
2. Initial Population
   Initial population in this study uses the results of the allocation of work elements Priority Rule-Based method. This method is very intuitive and can be combined with the meta-heuristic method. The use of Priority Rule-Based as an initial limitation will increase the effectiveness (partial) of enumeration procedures in the meta-heuristic method (Alena & Christian, 2014).
3. Crossover Probability
   Crossover probability which used in this research is 98%.
4. Mutation Probability
   Probability of mutation which used in this research is 2%.
5. **Cycle Time**
   Cycle time is determined based on takt-time to meet the target of 10 units / day, i.e. 2550 seconds or 42.5 minutes.

6. **Number of Iteration**
   The number of iterations is 100 times. Iteration will stop in accordance with a predetermined amount. The program will provide the best solution, the solution that has the highest fitness value.

### 3.2.2. Iteration process in Genetic Algorithm (GA)

In the iteration process in GA, it is necessary to determine the forming parameters namely initial population size, cross over probability, mutation probability and determine the maximum iteration in finding the best solution. The following are the iteration stages of GA.

1. **Generating initial population**
2. **Finding the fitness value of each population**, here are the results of the fitness value of each population
3. **Choose chromosomes that have the best fitness value**. Based on the fitness value on each chromosome, population 2 and population 4 are selected as the 2 best chromosomes.
4. **Furthermore, the two chromosomes become parents which will then be recombined**. At this stage 100 mutations and cross-over occur, so that the best chromosomes can be formed. Figure 4 is the process of mutation and cross over for 2 selected parents.

**Figure 4. Mutation Process**

Based on the calculation results of Mechanical Line 2 assembly line balancing, the actual condition of the allocation of uneven work elements at each workstation results in idle between workstations so that the production target is not reached (shown in Figure 5a). With the reallocation of work elements on the assembly line with priority rules (PRB), obtained a sequence of different work elements and have a better performance index than the actual conditions. The increase in line efficiency to 92% shows the level of work element allocation which is getting closer to takt-time so that it can optimize the time of workstations and the number of workstations can be minimized to 12.

**Figure 5. Existing Production Performance (a); Proposing Production Performance (b)**

After balancing the assembly line with the PRB method, the assembly line balancing is carried out with GA. The results of the allocation of work elements in the PRB method are inputted as an population population to get the possibility of a better allocation of work elements. The allocation of work elements that have a smoothness index value is lower than the initial smoothness index of population that is 745.07. The decrease in smoothness index shows the difference in time between workstations is not too large, so the proposed assembly line with the GA method is better than the...
actual assembly line. The comparation between existing condition, PRB Method and GA Method can be shown in Table 2.

**Table 2.** Existing Production Performance (a); Proposing Production Performance (b)

| Description          | Existing | PRB     | GA     |
|----------------------|----------|---------|--------|
| Line efficiency      | 85%      | 92%     | 92%    |
| Smoothness Index     | 7575.51  | 941.03  | 745.07 |
| Balance Delay        | 15%      | 8%      | 8%     |
| Work Station         | 13       | 12      | 12     |
| Number of Produced Unit | 7.65   | 10      | 10     |

4. Conclusion

Based on the problems and objectives of this study, it was concluded that, by balancing the assembly line Mechaical Line 2, the allocation of proposed work elements was allocated to each work station and the reduction in the number of work stations to 12 from the actual condition, namely 13 work stations. The balancing of the assembly line is done by allocating the work elements of each work station so that they do not exceed takt-time so that they have a better performance index than the actual conditions. Line efficiency increased to 92% from actual conditions of 85%. Balance delay decreases to 8% from the actual condition of 15%. The value of the smoothness index decreases from the actual condition of 7575.51 to 745.07. Based on the results of the actual assembly line performance index values and proposals, it can be concluded that the assembly line with 12 work stations is better than the actual condition of 13 work stations, because it has a better performance index and can meet the target of 10 units / day. For future research, to obtain sustainable results, consideration needs to be given to balancing assembly lines thoroughly, not just focusing on the mechanical line 2 area.

5. References

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