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Assembly Line Balancing Base Frame and Sub Assembly Excavator Using Genetic Algorithm Methods

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Abstract. In the company experienced an inachievement of production or lost demand. Based on the time each station has an inconsistency or no balance, so it can cause idle time. This occurs due to the allocation of workloads between work stations uneven so that there is unemployment in the operator and result in the buildup of WIP caused by a bottleneck on a workstation with a time station Significant work between other workstations. Therefore, the assembly line balancing is done by doing the minimation of the workstation and allocating the workload on the workstation. The balance in the placement of work elements and workloads on an assembly line can impact the efficiency of the line. The work station applied is a single model. The method used is a Meta-heuristic method of Genetic Algorithm used to balance the base frame assembly line and sub-assembly in the excavator assembly because this method can produce better solutions and Fast. In this research conducted 3 calculation scenario that is the condition to fulfill the time, the condition of utilization of existing workstations by utilizing 4 existing workstations and the condition increased demand 20%. So that the result of line efficiency in the scenario to fulfill the time at the base frame assembly of 100% of the actual condition of 60.45%, smoothing index of 0 so it can be said the line goes smoothly, balance delay of 0% then is said to be less idle time and the workstation has decreased from 4 workstations to 1 workstation, for a 100% sub-assembly line efficiency with the merging of each sub assembly into 1 workstation, smoothing index of 0 So it can be said the line goes smoothly, balance delay of 0% then it is said idle time is smaller. In the scenario utilization of existing workstation is the utilization of 4 workstations that exist line efficiency in the base frame assembly of 90.49%. In the scenario of demand increase 20% line efficiency of 100% with the number of workstations as much as 1 workstation, on the sub-assembly line to 1 station with the line efficiency of 100%, smoothing index of 0 so it can be said Line goes smoothly, balance delay is 0% then it said idle time is smaller.

Keywords: 1 Assembly line balancing · 2 Genetic algorithm · 3 Single model

1. INTRODUCTION

Excavators are heavy equipment produced on demand from consumers. Based on data obtained from the sales department of Heavy Equipment division, Recorded the sales in 2018 by 25 units. At the excavator assembly process in there are 3 assembly zones namely Zone A (Base frame assembly), Zone B (assembly upper Frame) and Zone C (final assembly) with the assembly line is single-model assembly line so as to produce one excava with one model requires only one assembly line. Here is the excavator assembly process flow can be seen in Figure 1.

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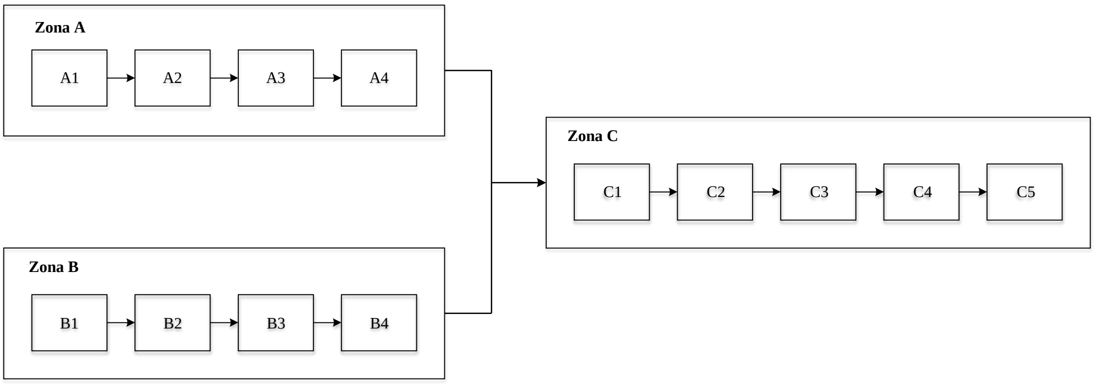


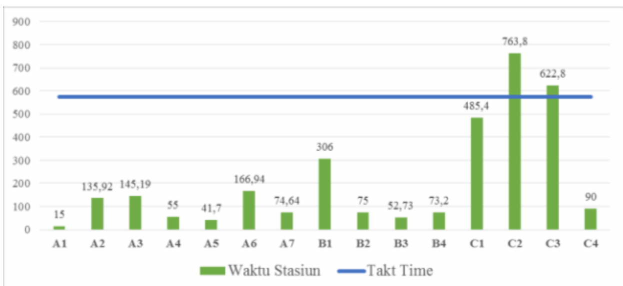
Figure 1 Flow Process Assembly Excava 200

For manufactures excavators per day with 5 working days and 6 hours of effective working hours. In 2018 set the production target of 3 excavator units per day to fulfill existing demand but in an actual state of excavator, products can only be in the production of 1 unit per day. In 2018 had a demand excavator of 131 units and the number of excavators that can be produced in 2018 as many as 119 units. It can be seen that there is a problem of the lack of production target in 2018 although there are inventory in the year 2017 as many as 7 units but in 2018 still experienced lost demand as much as 8 units can be seen on the chart Figure 1

Figure 2 Demand and Realisation 2018 Excavator

The scope of research carried out by the excavator assembly in zone A is the base frame assembly. Can be seen in Figure I. 3 time in excavator assembly for each zone have a significant difference. Thus, it can result in an imbalance of assembly lines. Can be seen in Figure 1, zone A and zone B is done in parallel then done next assembly in zone C is final assembly. The actual acquired time in the excava assembly 200 there is an imbalance in the assembly line with the time difference occurring in zone A and B so that it needs to be done line balancing to balance the time between zones assembly.

Figure 3 Distribution Station Time



Based on Figure I. 3 can be concluded that the assembly process in zone A has an ununiform process time so it can cause idle time. This happens because the workload between workstations is uneven so that unemployment occurs on the operator and result in the buildup of WIP caused by a

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bottleneck on a particular workstation that has a significant station time The largest time with the smallest station time. Each day has a buildup of 1 unit. Line balancing is then required in zone A by allocating workloads on workstations.

In the solving problem of assembly line balancing, the purpose of this research is to know the level of line efficiency, cycle time, and carried out optimally from the use of the selected method that is the most optimal performance level will be used as a solution for assembly line balancing issues. So the total time it takes each workstation is approximately the same and the total processing time at each workstation should be less than the cycle time or the maximum total time [5]. And if the compant implements a spinal configuration, it can make it easier for suppliers to send subassemblies directly to the assembly position by grouping in the assembly can increase the efficiency of the track[4].

The method of balancing the line that will be used as a research in resolving line balancing problems is the Genetic Algorithm method to minimize workstation which is a metaheuristic method of search methods designed to produce more solutions Good and fast. This method can solve the problem of searching with the size of the growing problem that will increase so that if there is a change in problems that are increasingly complex then this method can overcome. Assembly line balancing is done in zone A (base frame), Subassembly box power, subassembly floor cabin assy and subassembly hydraulic oil tank.

2. Literature

2.1 Assembly Line Balancing

Assembly line is a production line consisting of a number of assembly operations performed on several workstations and combined into assembly product or sub assembly[2]. The following steps are performed in balancing the assembly line[2].

1. Establish a diagram precedence informing the relationship and sequence of the assembly process and the linkage between the working elements of the assembly line.
2. Cycle time
   Cycle time is the time produced on one workstation in the process of completing the assembly of a product. Cycle time can be calculated with the formula:

$$CT = \frac{Production\ Time\ per\ hari}{Output\ per\ day} \quad (1)$$

3. Minimum number of work stations

After determining the cycle time interval, then the number of Efisein workstations can be calculated with the following formula:

$$K_{min} = \frac{\sum_{i=1}^{n} ti}{C} \quad (2)$$

De
scription:

TI: Time Element (i = 1, 2, 3..., N)

C: Cycle time

N: Number of elements

K_min: Minimum workstation number

4. To meet the cycle time restriction, it can be struck using the formula:

$$N = \frac{Total\ time\ work\ element}{cycle\ time} \quad (3)$$

5. Assembly Line Balancing method

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The choice of method in solving the assembly line balancing problem is important to get optimal results. Assembly line balancing can be done with an exact or heuristic approach with multiple methods.

6. Balance Delay

Balance Delay is often referred to as balancing loss, which is the size of the size inefficiencies resulting from the actual idle time caused by the less-than-perfect allocation between workstations.

$$D = \frac{(n\ x\ C) - \sum_{i=1}^{n} ti}{(n\ x\ C)}\ x\ 100\% \quad (4)$$

Description:

N : Number of workstations

C : Largest cycle time in workstations

$\sum_{i=1}^{n} ti$: Number of operating times of all operations

TI : Operating time

D : Balance delay (%)

7. Line Efficiency (LE)

That is the ratio of the complete amount of each working element to the number of multiplication between workstations and cycle time on the assembly line. The ratio of presenting the balance of work elements to the workstation. Line Formula Efficiency:

$$LE = \frac{\sum_{i=1}^{k} STi}{(k)(CT)} \quad (5)$$

Keterangan:

STi = workstation i

k = total workstation

CT = *Cycle time* maximum

8. Smoothness Index (SI)

Smoothness Index is an index that shows the relative of an assembly line balancing. When Smoothness Index is 0 it is perfect.

Smoothness Index formula:

$$SI = \sqrt{\sum_{i-1}^{k} (STmax - STi)^2} \quad (6)$$

Description::

STi = station time i

k = total workstation

$STmax$ = station time maksimum

Mathematics Model Assembly Line Balancing

According to actual production conditions, the mathematical model set for the resolution of the assembly line balancing problem [12].

1. Purpose function

Minimation Workstation

$$\sum_{k=1}^{k} X_{ik} \leq nA_k \qquad (i = 1,2 \dots k) \quad (7)$$

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2. Constraint function
   a. Constraint assignment function

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To ensure the process of product assembly and final product integrity, all work must be assigned to various assembly workstations.

$$\sum_{k=1}^{k} X_{ik} = 1 \qquad (i = 1,2 \ldots n) \tag{8}$$

b. Cycle Time Constraint function
The operating time on each workstation must not exceed the specified production cycle time.

$$\sum_{i=1}^{n} X_{ik}\, T_i \leq CT \qquad (k = 1,2 \ldots k) \tag{9}$$

c. Constraint Precedence function
Order of work that must be a precedence in assembly. Determination of work to be completed before or after work and allocating from one workstation to another.

$$\sum_{k=1}^{k} (KX_{jk} - KX_{ik}) \geq 0 \qquad ((i,j \in pred) \tag{10}$$

2.2 Genetic Algorithm

The genetic algorithm is a search strategy using encoding and representation of the problem parameters to be searched by using operations such as selection, recombination, and mutation to improve the search measured by fitness or evaluation function. The initial population is the beginning of a genetic algorithm done called chromosomes or coding solutions and using an operation called suggest alternate solution[6].

Essentially, when the number of workstations assigned to the assembly line, when the number of workstations assigned to the assembly line the representation of the solution to the ALB issue was that each gene was a workstation number. In other words, the number in the I-gene inside the chromosome is the workstation where this task will be assigned. Below is a presentation of the following initialization process to produce a decent chromosome. The following characteristics in the structure of the genetic algorithm for assembly line balance problems are as follows:

a. Coding (coding)
Each element of the work is represented by a number that is put yarn (chromosome) with the size of yarn, equal to the number of elements of the work.

b. Fitness Function
The Fitness function is an individual evaluation of a specific function as a performance measure. In the natural evolution of a survival, individual is a high-value fitness person, while the deceased individual is a low fitness. The first part of the fitness function aims to balance the best solution from the result of the same number of workstations, while the second part to minimize the number of work stations.

$$Fitness\ Funcio = \sqrt{\frac{\sum_{k=1}^{n}(Smax - S_k)^2}{n}} + \frac{\sum_{k=1}^{n}(Smx - S_k)}{n} \tag{11}$$

Where:

n = number of workstations

Smax = Maximum work station time

S_k = time of work station K

c. Initial population

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Produced by guaranteeing the initial population feasibility randomly generated with precedence relations.

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d. Crossover and Mutation (interbreeding and mutation)
At the crossover, the stage is the stage of maintaining some of the best solutions and eliminating the solution less good. The result of a crossover depends on the chromosome in the old generation or parent. At the stage of the mutation was done modification of one or more genes in the same individual to create a new individual, by replacing the missing genes of the population. During the selection process, the lost gene will be replaced by providing a gene that does not exist in the initial population[7].

e. Scaling (Pengskalaan)
To activate the value selection procedure by scaling the fitness value so that the total value of the fitness scale equals to 1.

f. Selection procedure
The selection of two chromosomes as parents (parents), which is done proportionally according to fitness value and will be moved.

g. Stopping Condition
The state of its stop is an algorithm after multiple iterations.

3. Discussion

Assembly line balancing using the genetic algorithm method with MATLAB software. Data used is the actual data to obtain an efficient assembly sequence with the consideration of the allocation of work elements so as to minimize the workstation and maximum workstation time does not exceed takt time. This research was conducted to obtain the balance of the assembly line with several scenarios:

a. Line balancing with current work station minimisation taking into account the takt time so that the cycle time is generated under takt time
b. Increase the production capacity by utilizing the existing workstation that is 4 workstations on the base frame assembly.
c. Line balancing with increase demand 20%

3.1 Genetic Algorithm using MATLAB Software

Here are the parameters in the application of genetic algorithm calculations on the balance of assembly lines, namely:

1. Population size
The population is a chromosome containing a gene that contains a sequence of working elements that notices the interconnectedness of the working element. In this study, the population size used is as much as 3 populations.
2. Initial population
The population in the calculation of the assembly line balancing with the genetic algorithm method using random or heuristic methode.
3. Task Time
The matrix containing the operation time of each element of work that will be used to calculate the balance of the assembly line.
4. Probability Crossover
The crossover probability used in this study was 98%
5. Probability Mutation
Mutation probability used in this study is 2%
6. Number of iterations
The number of iterations used in this study is 100 to get individuals with the highest fitness value that would be the best solution

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3.2 Results Running Genetic Algorithm Program Using MATLAB Software

The following are the results derived from the calculations using the genetic algorithm method based on pre-defined parameters.

a. Cycle time based on takt time

In meeting the target company and minimizing WIP so that the installation of an assembly line in zone A which has a significant time to takt time so that the work station minimized to increase the time of station so that it can Increase station time. And the merger of the workstations in sub- assembly so as not to happen WIP on the assembly line. The following allocation of work stations can be seen in Figure 4.

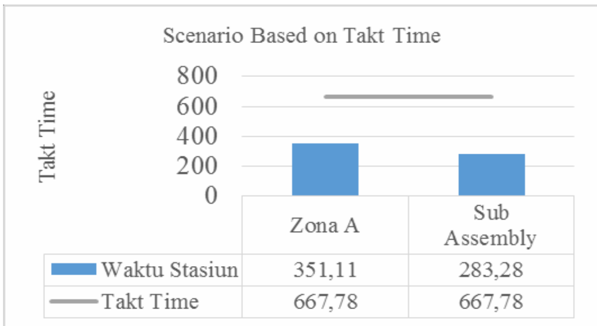


Figure 4 Allocation workstation based on takt time

b. Cycle time base on 4 workstation

Here is a proposal if the company wants to raise the production capacity and utilize the existing facilities by balancing at the time of each workstation. The following is the time allocation of workstations in the base frame assembly can be seen in Figure 5.

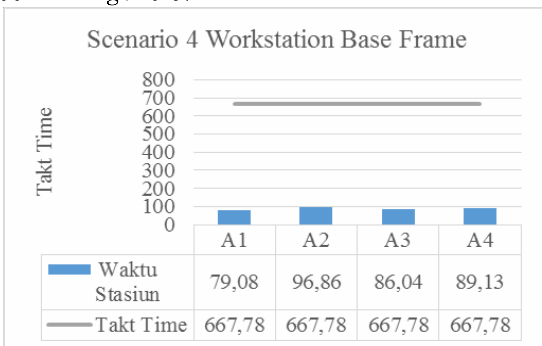
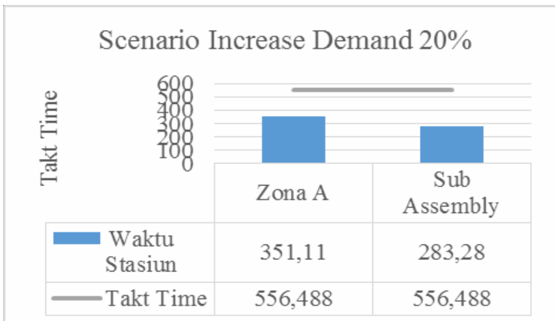


Figure 5 Allocation workstation based on 4 workstation

c. Cycle time based on increased demand 20%

Here is the proposed allocation of the workstation when the company has increased by 20% can be seen in Figure 6.



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.Figure 6 Allocation workstation based on increase demand 20%

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2.3 Index Performation of The Results Running Genetic Algorithm Program Using MATLAB Software

Based on the data processing done in the research using the following 3 scenarios is the result of the recapitulation of actual condition Performance index and proposed with predefined parameters and variables can be seen in Table 1.

Table 1 Index Performation Current and Proposed

	Currents	Proposed		
	Condition existing	Condition *takt Time*	Condition 4 Work Stations	Condition increase *demand* 20%
balance Delay	39.54%	0%	9.37%	0%
line Efficiency	60.45%	100%	90.49%	100%
smoothing Index	158.65	0	22.20	0
Number of Work Stations	4	1	4	1
Stmax	145.19	351.11	96.86	351.11
Assembly Line Capacity	3	1	4	1

Line assembly is said to be good if the line efficiency approaches 100% i.e. line approaching efficient condition, balance delay approaching 0 is said to be less idle time, and smoothing index approaching 0 is said to be a smooth assembly line. Can be seen in Table 1 index actual performance and the proposal can be seen that there is an increase in line efficiency in the 3 scenarios set. If the company wants to fulfill demand with takt time currently can do the first scenario solution in order not to happen WIP buildup. If the company wants to raise the production target and utilize the existing facilities then use the second scenario. And if the company has increased demand can use the third scenario.

4. Acknowledgements

The following is a feasibility analysis of the application of the proposal to be used by the following companies as a consideration of the proposal based on 3 research scenarios that have been conducted:

1. The result of the balancing of the assembly line resulted in the reduction of the workstation so that in its application the company must reallocate or redesign the unused workstation for the other work so it needs to do the design Layout again.
2. The result of the balancing of the assembly line that corresponds to the target or the takt time is conditional in the case of changes in production target increase or decrease in demand then the configuration of rebalancing of the line is required.
3. The result of the balancing of the base frame assembly line in zone A needs to be fit with the swing frame assembly line in zone B, because both zones are parallel and an input part for zone C is final assembly. When zone A and zone B cycle times have significant time difference, inventory, if the system applied on an assembly line, is a push system. So it is expected that the system applied to this assembly line uses a pull system to minimize inventory.
4. Application of genetic algorithm is done initial parent determination that can be done by generating randomly or with a certain heuristic method, then application conducts fitness evaluation of each chromosome x in population, then Generate new populations. In gaining a new population the system will do the selection of parents chromosomes picking from the population with their fitness, crossover is carried out with a 98% crossover probability aiming to form a new offspring (offspring) when not The crossover is formed then the result of offspring is purely from its parent, mutations with a mutation probability of 2% formed offspring a new one on each locus (the position of the chromosome). In 100 iterations or generations did not undergo a line efficiency change of 100% due to the total work station generated in the calculation of the genetic algorithm 1 workstation, so the optimum condition was reached in the first iteration.

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