Redesign of Facility Layout with Graph Method and Genetic Algorithm in Wood Manufacturing Plant

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Abstract. Facility planning is a plan for a facility to operate synergistically in the production process, in accordance with the planned objectives. PT. XYZ is a manufacturing company in the industry that uses wood for furniture. The layout of facilities at PT. XYZ has found an irregular material flow pattern so that there is a line crossing from the joint station to the laminating station and tapping station to the cutting station. Inefficient production lines also produce quite long production lines. In solving this problem, graph methods and genetic algorithms are used. The graph method uses from to diagrams to make proximity graphs based on the greatest weight. Genetic algorithms are based on the principles of genetics and natural selection. The genetic algorithm uses a generation mechanism so that the optimal layout results are obtained. The results showed that the actual moment of total displacement was 3,422,846 meters/month, the total moment of displacement using the graph method was 926263.69 meters/month, and the total moment of movement using the genetic algorithm was 756439.1 meters/month. The results showed that the improvement of the layout using genetic algorithms was chosen because it had an efficiency of 77.90%, higher layout improvements using graph methods with an efficiency of 72.90%.

1. Introduction
Timber companies in North Sumatra have developed rapidly. This is from increasing demand, especially for export abroad. The industry for processed wood began to be developed and exported by factories in the territory of Indonesia, which around 1986 followed the policy issued by the government which "forbade the export of logs and only allowed to export sawn timber and similarly processed wood, such as cabinets, chairs, and other furniture needs". North Sumatra Province is an area that has the second largest rubber plantation area in Indonesia and has many wood processing industry companies, most of which are made from rubber wood. This company produces various types of furniture products such as appliances/furniture, including chairs, tables, carts, shelves, clothes hangers, cabinets and so on which are generally exported abroad (Japan and Europe) [1,2].
Based on the results of surveys to similar companies related to the production process, there is process cycle efficiency and low processing productivity. The reason is that there are still many non-value added activities in the production floor on the production floor, such as the long distance and transportation activities. Also, because so many types of parts or products cause irregular material flow and cross movement.

The company studied as a comparative study is PT. XYZ because it has more product types and a more complete process flow. The production system of this company is Make-to Order (MTO), where each product is made based on orders from consumers. The company has 13 workstations on its production section.

Facility layout problems is defined as facility placement in the factory area, with the aim of determining the most effective arrangement according to several criteria or objectives under certain limits, such as shape, size, orientation, and take-off/drop-off point of the facility [3].

Based on observations, the flow of material on the factory floor of the company has not been smooth. There is a material transfer flow that experiences cross movement from station f-joint (III) to the laminating station (IV) and the station (I) to the cutting station (II). Then there is a transfer of material that has experienced backtracking from the cutting station (II) to the f-joint station (III). Irregularities in production trajectories also result in long enough trajectories of production. The longer production path distance will increase the total moment of displacement so as to reduce the efficiency of material removal activities on the production floor. Production floor layout of PT. XYZ can be seen in Figure 1.

Irregularities in production trajectories also result in long enough trajectories of production. The longer production path distance will increase the total moment of displacement so as to reduce the efficiency of material removal activities on the production floor. If this problem is left unchecked, it can certainly hamper the overall production process.

![Figure 1. Facility Layout in PT. XYZ.](image-url)
From the above problems, it is necessary to redesign the proposed production layout. The main objective of the planning of facility layout is to minimize the distance of costs and time spent in manufacturing systems. An efficient and effective facility layout can include to provide optimal space for organizing equipment and facilitate the movement of goods and to create a safe and comfortable work environment, reduce movement of workers, raw materials, components and equipment, facilitate expansion or change layout to accommodate lines new products or technology enhancements and increase organizational production capacity [4].

The method used in rethinking the production floor layout using the Graph Method and Genetic Algorithm. The graph method is chosen because it can solve layout problems based on the flow of the production process and the displacement of each product component [5]. The genetic algorithm is chosen because it can solve the problem of chromosome layout which is the number of workstations will experience the selection, crossover, mutation, and iteration processes according to the criteria that have been established [6]. The genetic algorithm finds an optimal problem solution that can be applied to the layout [7].

2. Methodology/Experimental
Data processing in this research uses the following steps:
- Frequency of transfer
  Frequency is calculated based on observations and the amount of material produced.
- Distance between departments
  The distance is calculated based on the real conditions on the production floor at PT. XYZ.
- Calculation of Initial Transfer Moments
  The initial displacement moment is obtained from the frequency times with the distance traveled by the flow in the production process.
- Make From To Chart
  From To Chart is used as a tool for graph methods. From To Chart is based on the total moment of displacement [8,9].
- Redesign the layout using the graph method
  The design is done based on the biggest weight made into the proximity graph [10].
- Redesign with the help of genetic algorithms
  The design is done through the selection process, crossover, mutation, and iteration according to the criteria that have been set [11].
- Evaluation
  After facility layout design using the Graph method and Genetic Algorithm, the calculation of the total distance of displacement of each method is carried out. Calculation of moment efficiency ($Me$) with the following formula [12]:

$$Me = \frac{(di - do) \times 100}{di} \quad (1)$$

where is: $di$ = the total displacement distance of the initial layout (meters/month)
$do$ = total displacement distance of the proposed layout (meters/month)

3. Results and Analyze
3.1. Frequency of transfer and Distance Between Department
The frequency is carried out based on the amount of material used with material handling capacity to transport materials. The distance is done by the aisle method which is the distance obtained based on the production path. The results are calculated based on Table 1.
Table 1. Frequency of transfer and Distance Between Department.

| First Work Centre | Last Work Centre | Total Frequency (times/month) | Distance (m) |
|-------------------|------------------|------------------------------|--------------|
| I                 | II               | 13908                        | 105.42       |
| II                | III              | 11525                        | 98.85        |
| II                | VI               | 281                          | 98.95        |
| II                | VII              | 1134                         | 99.12        |
| II                | VIII             | 690                          | 99.96        |
| III               | IV               | 222                          | 15.76        |
| III               | VII              | 34                           | 150.47       |
| III               | VIII             | 144                          | 151.36       |
| IV                | V                | 214                          | 171.69       |
| V                 | VI               | 142                          | 84.35        |
| V                 | VII              | 68                           | 84.52        |
| VI                | IX               | 592                          | 88.86        |
| VII               | IX               | 519                          | 89.03        |
| VIII              | VI               | 376                          | 63.84        |
| IX                | X                | 1111                         | 176.18       |
| X                 | XI               | 1845                         | 36.11        |
| XI                | XII              | 1845                         | 48.09        |
| XII               | XIII             | 1111                         | 45.42        |

3.2. Total of Material Handling
Total moment of displacement distance can be obtained from the results of frequency times with displacement distance. Based on the calculation formula for the total moment of the displacement distance, the calculation results obtained are 3422846 meters/month.

3.3. From To Chart
From To Chart is made based on the moment of movement between stations [13]. The results of the From To Chart can be seen in Table 2.

Table 2. From To Chart.

3.4. Layout Redesign Using Graph Methods
Graphic design method uses the adjacency graph as a link between existing stations. The goal is to get the biggest weight [14]. The input from this method is From To Chart. From To Chart in Table 2., a graph of proximity is formed through the planar triangle. This planar triangle is arranged based on the
weighting of departmental pairs that have the largest transfer frequency. The results of the graphical method in the form of block graphic proximity layout can be seen in Figure 2.

![Figure 2. Block Layout Graphic Proximity.](image)

Then the stations are arranged on the production floor based on a proximity graph which can be seen in Figure 3.

![Figure 3. Proposed Layout Using Graph Methods.](image)
Calculation of the moment of displacement distance to the proposed layout using the Graph method is done in the same way as the actual layout. The result is the total moment of displacement is obtained at 926263.69 meters per month.

3.5. Layout Redesign with the Help of Genetic Algorithms
Designing with genetic algorithms is done with the following steps [15]:

- **Representation of solutions**
  The chromosome is a representation of departmental placement for each location. Each gene in the chromosome shows the workstation. The length of each chromosome is the same as the number of workstations.

- **Determination of parameters**
  In this study the fitness value of individuals is best monitored in each generation, so the parameters used are:
  - Population size = 80
  - Preservation probability (kb) = 0.2
  - Maximum generation = 10

- **Initialize the initial population**
  The population size used (popsize) is 80. Initialization of chromosome contents is done randomly.

- **Selection**
  This selection aims to provide greater reproductive opportunities for the fittest members of the population. Selection will determine which individuals will be selected for recombination (crossover). Population selection is carried out using the roulette wheel selection method or selection of roulette wheels [15].

- **Crossover**
  Crossover (crossing) is done on 2 populations to produce a child population (offspring). The chromosomes of children formed will inherit a portion of chromosomal population. The crossover method used is the order (OX) method.

- **Mutations**
  Mutations are done to get individuals who have the best fitness value by replacing one or more genes from selected individuals.

- **Chromosome preservation**
  The best chromosome probability to be conserved is 0.2, which means that at least 20% of the chromosomes in the population that have occurred (16 populations from 80) will be replaced with the best chromosomes in the initial population of the generation concerned. Then the final population is produced which will be the initial population of the second generation. Then it is done in the same way for the next generation.

- **The results of the genetic method obtained the best fitness with a value of 0.0000005941. The best fitness genes are arranged in the form of the layout as in Figure 4.**

- **Calculation of the moment of transfer to the proposed layout with the help of genetic algorithms is obtained at 756439.10 meters/month.**
Figure 4. Proposed Layout Using Genetic Algorithm.

The floor layout of the proposed production with the graph method does not have cross movement and backtracking. The layout is carried out in accordance with the flow of the production process starting from the submarine station (I) to the packing station (XIII). The total moment of displacement generated from the graph method is 926263.69 meters/month and the reduction in the moment of displacement with the actual layout is 2496582.31 meters per month. This shows a moment efficiency:

\[
\text{Moment efficiency } (Mo) = \frac{3422846 - 926263.69}{3422846} \times 100\% = 72.90\% 
\]

The floor layout of the proposed production floor using a genetic algorithm does not have cross movement and backtracking. The layout is carried out in accordance with the total flow moment of the displacement generated from the graph method of 756439.10 meters/month and the magnitude of the reduction in moment of movement with the actual layout of 2666406.9 meters per month. This shows efficiency of:

\[
\text{Moment efficiency } (Mo) = \frac{3422846 - 756439.10}{3422846} \times 100\% = 77.90\% 
\]

Based on the results of calculations, it can be seen that the proposed floor layout with the help of genetic algorithms at PT. XYZ has a good flow.

4. Conclusions

Based on the results of the processing and analysis, it is obtained a moment of displacement distance from the initial production floor layout at PT. XYZ is 3422846 meters per month where there are cross movement and backtracking. The moment of displacement distance of the proposed facility layout with the graph method is 926263.69 meters/month smaller than the total moment of the initial displacement with a moment reduction of 2496582.31 meters/month. The moment of displacement distance from the proposed production floor layout with the help of genetic algorithms is 756439.10 meters/month smaller than the total moment of the initial displacement with a moment reduction of 2666406.9 meters/month. The moment efficiency of the graph method is 72.90% smaller than the efficiency of the moment with the help of genetic algorithms which is 77.90%. Then the genetic algorithm is chosen to be the proposed floor layout design in PT. XYZ. The design of the floor layout
for the production of proposals with genetic algorithms does not experience cross movement and backtracking.

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