Production scheduling using ant colony optimization in furniture industry

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Abstract. Every association tries to always create an effective and efficient production process. High competition in the industrial world during this time has led to industrial growth which has influence to a company to increase overall productivity in their production activities. For a production activity, in order to obtain an optimum result, all production activities must first be planned properly. Production scheduling is very important in the production process of a product in the company. The first come first served scheduling system currently implemented by the company capable to produce an appropriate scheduling. This causes the high total lead time (makespan) resulted and makespan obtained does not meet the due date. Therefore, it is necessary for rescheduling in order to decrease the overall total lead time to meet customer orders. The study design uses the ant colony algorithm to design the scheduling of door leaf production. The result shows that production scheduling using the ant colony algorithm resulted in scheduling sequences based on the length of lead time are job 1- job 6- job 4- job 3- job 5- job 2. The ant colony method is able to decrease slightly the total lead time product of 3,06%.

1. Introduction
Scheduling is concerned with efforts to see that the resources of a manufacturing system are well utilized so that the products are produced within reasonable accord with the customer demand [1]. Scheduling is the activity of allocating existing resources or machines to carry out a set of tasks using a certain period of time [2]. Scheduling also means the order process of product making as a whole on several machines [3]. The production scheduling problems are set in order to get an optimum management control of the production process. They are often characterized as complications of providing specific numbers of output, in the required tempo and high quality [4].

Determination of the company resources allocation (human resources, capacity resources and production equipment or machinery, and time) is shown to realize the target of effective and efficient use of resources while producing outputs are the right quantity, on time and on the right quality [5]. A production scheduling consists of various aspects, namely a production quantity, production time, production costs, production machines quantity, and the availability of raw materials for production. In the aspect of raw materials availability, production is said to be optimal by minimizing production costs. All aspects of production affects each other, so scheduling planning is made more complex. In addition to production, other things needed as the consideration for companies include the raw materials requirement, because capable to produce a product, the raw materials requirement must be available before the production process begins. Therefore, the quantity of raw material inventory also consider into calculation [6]. Therefore, proper production scheduling is desired to reduce ineffective time and increase productive time during the production process.

This furniture industry produces doors leaf are allocated abroad. Doors leaf are produced by industries based on consumer wish. Industry produces various doors leaf with 6 different types of doors. The type of applied production system is called a flow shop. Flow shop scheduling has a static
flow, whereas job shop scheduling is dynamic [7]. In this specific system, all products go through a production process with the use of the same machine. The steps of product processing using the equivalent machine are related to increase customer demand and fluctuates indirectly which causes accumulation and irregular product waiting times. Previously mentioned condition causes delays in the products delivery to consumers. Thus, the scheduling design is required for decreasing total lead time to meet customer demands.

Some scheduling models generally assume that every production process is always done at the same production location so that there is no inter-process transportation time. In fact, there are some companies do not process production at the same production location, so there is a transportation time between processes in series and all work operations carried out in the same order or route [8]. Production scheduling handling can be done with diverse methods, an example is the Ant Colony Optimization (ACO) Algorithm method. ACO algorithm was developed based on the foraging behavior of ants in their colonies where pheromone is the substance used to communicate amongst the individuals [9,10]. Ant colony optimization is a metaheuristic approach which can be used to solve optimization problem [11]. Ant colony algorithm is first introduced by Dorigo, Maniezzo, and [12]. This method has been applied in previous studies to increase the speed of the road network [13], for solving 3D TSP [14], for solving the shortest path problem, and the other research. This research was done by designing a door leaf production schedule based on the amount of consumer demand received.

2. Methodology
The present study was operated in a furniture industry in the city of Medan. The object of study is the job order of door leaf production processes. The study began with direct examination of the furniture industry. Based on the observations, the determination of the problem formulation determined by according to conditions occur in the company. The problem formulation will determine the research objectives achieved [16]. Furthermore, data collection used as an input in conducting this research. Data collection in the form of product cycle times, demand, production capacity, and machines quantity used. Based on this data, an analysis of production scheduling is carried out which is the aim of this study. Production scheduling is designed using the Ant Colony Optimization method. This method is an optimization algorithm inspired by ant behavior in searching for food. Because of the advantages, ACO is widely used to solve difficult non-polynomial problems, one of them is edge detection in images. In the first step, ACO spread ants randomly, this cause an imbalance in the ants distribution which affects the finding line process [17]. Scheduling with this method requires data starting from the time of each processing (Processing Time) as a variable to find the smallest makespan time, in this process the data is processed using graphs, the process is carried out to represent the data flow shop where the data is entered into nodes in the data flow which is interconnected with one another so that it can be used to determine the shortest route of the process.

3. Result and discussion
Production scheduling constructed by using the Ant Colony Optimization-Taboo Search method [18]. For this step requires data - starting from the time of each processing (Processing Time) as a variable to find the smallest makespan time, in this process the data is processed using graphs, the process is carried out to present data flow shop where the data is entered into nodes in the data flow which is interconnected so that it can be used to determine the shortest route of the process. A graph represents the overall door leaf production process is shown in Figure 1.
Then a calculation is made where the basic principle in this calculation is to process an empty initial solution until it becomes a final solution. Each step done is obtained by based on the cost calculation done by each iteration to choose a neighbor solution that will be the next current best solution. Termination of the process occur when the smallest makespan value obtained. Cost calculation is a very important process. Cost calculation detect violation of constraints for each production. The high cost, it can be concluded that the schedule held contains many violations of soft constraints. Detection of this violation is done to determine which production should be repaired, then determine which door leaf product should be chosen to improve the production schedule. It can be said that success in determining a solution has a high level of correctness depends on the method used to determine the production cost. After identify the problem, a cost matrix is obtained for scheduling machines in the company as follows:

\[ WC = \text{work center and Job = assigned job} \] (1)

Based on the iteration results, it is found that the best job order of door leaf products are job 1-6-4-3-5-2 with a lead time of 2500.54 hours as shown in Table 1.

| Machine | Job Order | Job 1 | Job 6 | Job 4 | Job 3 | Job 5 | Job 2 |
|---------|-----------|-------|-------|-------|-------|-------|-------|
| A       | End       | 0     | 70.92 | 76.75 | 79.58 | 204.95| 209.44|
|         | Start     | 70.92 | 76.75 | 79.58 | 204.95| 209.44| 466.25|
| B       | End       | 70.92 | 178.66| 188.59| 204.95| 414.74| 466.25|
|         | Start     | 178.66| 188.59| 193.69| 414.74| 422.44| 878.01|

Table 1. Result of lead time (makespan)
The Gantt chart for job order of 1-6-4-3-5-2 for each machine can be seen in the figure below:

![Gantt Chart](image)

**Figure 2.** Gantt chart of door leaf production process

From the Gantt Chart above it can be seen that with job order are 1-6-4-3-5-2 has a 2500 hour makespan.

4. **Conclusion**

Production scheduling is required to dodge delays in the products delivery to consumers, notably for products that require a long lead time. In this study, the scheduling design is carried out using the Ant Colony Optimization method of the product i.e. work A with job order are 1-6-4-3-5-2 for each machine. The results indicate that with a lead time of 2500.54 hours using the Ant Colony Optimization method.

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