Minimization of Makespan Using FCFS and Gupta Method Comparison in Machine Spare Part Industry

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Abstract. Companies that produce spare parts for manufacturing industry machines are experiencing rapid development. The company produces production activities based on job orders where the process uses FCFS (First Come First Served) rules. Company scheduling often experiences delays especially on products have the same flow. The study was conducted to find the optimal sequence of scheduling with makespan minimization criteria using the Gupta Method and FCFS Method. The FCFS method used by the company produces makespan of 12,160,21 minutes = 202.67 hours. The recommendation method has a better level of performance compared to the company shown in efficiency index (EI) and relative error (RE). The EI value of the Gupta method is 1.14 which indicates that the Gupta method has a good performance compared to the FCFS method. While the Gupta method RE value is 13.76%. The conclusion is Gupta method produces the minimum makespan value with a reduction of makespan of 178.15 hours. The Gupta method is a better method than FCFS method, which is shorter makespan, tardiness and flow time.

1. Introduction

A company's performance will not be optimal if the company is only trying to maximize the use of existing resources without looking at other factors. Companies must make a systematic work plan and the company can provide good service to consumers by sending products on time and completeness of production in accordance with the due. A systematic work plan can be carried out by scheduling measurable production. Good scheduling will have a good impact on increasing the effectiveness and efficiency of the company's production system so that it can reduce production costs.

The problem often occurs is that the production process activities on the production floor often experience delays in activities through the same machine. Delays occur due to the use of the same machine for working on different products. In addition, the type of product variation and the stage of the work process with the use of the same machine also causes delays due to the bottleneck. Therefore, rescheduling is needed to minimize the total completion time in order to meet customer orders. Scheduling can be defined as the allocation of resources over a period of time to perform a collection of tasks [1]. Makespan minimization in tasks scheduling is important of infrastructure [2]. The theme of scheduling in distributed clusters and systems is one of the important themes in utilizing available resources and reducing response time. Job scheduling software are some important software in groups that are often used. The job scheduling function involves allocating the right processor and further maximizing the use of system resources and reducing the average response time created from existing conditions [3]. Regarding scheduling in parallel has been very widely used, scheduling is very
useful in the application of knowledge. Work in parallel consists of several processors that perform simultaneously all of which do certain calculations [4]. Dissimilar job and process scheduling algorithms are often used for very long periods of time in various domains such as microprocessor-based systems, software production management techniques [5]. Production scheduling is one of the significant factors related to consumer demand. This is interrelated with the optimization of several indicators, including performance indicators, all of which are directed towards the functioning of the system and customer satisfaction, such as: efficient use of resources, delivery of products with a given deadline, and reduction of production costs [6].

By far the modest scheduling algorithm is the first-come, first served scheduling (FCFS) algorithm. With this system the process that requirements the object first is allocated the object first. The implementation of the FCFS policy is simply succeeded with a FIFO queue [7]. NEH (Nawaz, Enscore, Ham) Algorithm is an efficient algorithm that works by minimizing the makespan. There are algorithm issues in job scheduling where are theoretical and applied research can both contribute a lot of solutions. First come first served scheduling a modest job scheduling method which can frequently be found in actual systems but is regularly measured insufficient by numerous researchers. Many workloads good performance can be expected from an FCFS schedule [8]. Gupta anticipates heuristic techniques to reach the makespan to the minimum. In the Gupta heuristic algorithm, all work is divided into two parts by linking the allowance time of the first machine and the last machine in each job. For each group, analyze the quantity of processing time from two end-to-end tasks in a job and find the minimum processing time, and then schedule the work in sequential order according to the minimum processing time added [9, 10]

Production forecasting problems [11] and the problem of production scheduling has been resolved in previous studies. The study was conducted at one of the juice companies have 5 different production flows. The study was conducted using the Gupta method by Soheil Sadi-Nezhad and Samira Borhani Darian and managers were easier to make decisions and an effective way of making production scheduling models [12]. The new tie-breaking mechanism is based on the estimated idle time of various work sequences in selecting jobs then the one with the lowest estimated value. Some computational combinations carried out by them show that this mechanism outperforms preexisting, both for FCFS and iterated greedy algorithms for different CPU times [13].

Based on the research has been done before, this study uses the FCFS method and the Gupta method. The Gupta method is used in analyzing production scheduling which is has a series of machines with a number of jobs (n-job m-machine). The FCFS method is used by companies to obtain the minimum makespan value and it can reduce the level of delay occurs on the spare parts company. The study was conducted by comparing the performance of the FCFS method with the Gupta method to get a better method in minimizing of lead time.

2. Methodology

The study was held in industries engaged in spare parts machine in Medan city where the objects studied in this research is doing production sequencing processes and the production scheduling system for each spare part machine. The study begins with observations to observe and see the state of the company directly. From the results of observations, it is determined the formulation of the problem in accordance with the conditions occur in the company and the research objectives can be applied. The research objectives determined are a solution to real problems. Furthermore, the data collection is the input in conducting this study. Data needed in the form of cycle time, standard time, number of demands and the number of machines used. Cycle time is obtained by measuring time using a stopwatch time study. The stop time watching study technique is to use the most basic and easiest time measurement method, and this method is usually used rather than other time measurement methods [14]. With these data, data processing is carried out with several stages, namely conducting data uniformity test, data adequacy test, standard time calculation and calculation of lead time (processing time), and production scheduling. The cycle time has been obtained from the measurement results is then given allowances in the westinghouse
method and normal time can be input into the standard time calculation. Calculation of standard time is done for each type of door leaf in the entire work center with the formula:

\[ W_s = W_n \times \frac{100\%}{100\% + \text{Allowance}} \]  \hspace{1cm} (1)

With the formula above, a standard time will be obtained which will be used to calculate the lead time. Calculation of lead time is measured using the following formula:

\[ \text{Lead Time} (t_{ij}) = \text{Setup time} + \left( \frac{\text{standard time} \times \text{demand}}{\text{product capacity (unit/process)}} \right) \]  \hspace{1cm} (2)

Then production scheduling is carried out using the First Come First Served (FCFS) and Gupta method. Production scheduling using the FCFS method is done to make the makespan minimum with several steps. The first steps are the amount of the processing times of each job and do the sequence of jobs affording to the amount of processes opening from the largest to the smallest and the results of this classification are called the list of sorting jobs. Then take the job of rank primary and another on the list of job sequences then calculate the number of partial makespan and mean flow time to determine the selected partial sequence with the smallest makespan value, then do the similar steps as in the previous stage until the overall sequence of jobs is obtained. Purpose of job arrangements is done by observing at the smallest makespan rate for each job. Scheduling with the Gupta method is done by adding up the lead time of the closest machines to obtain the minimum value of the minimum time to determine the value of EI and SI. Furthermore, the calculation results are sorted from jobs have the largest to the smallest value. Then the best method is chosen to produce the minimum makespan between the Gupta method and the FCFS method. Gupta and FCFS in this research are combine method.

3. Result and Discussion

3.1. Uniformity Data Assessment and Adequacy Data Assessment
The uniformity data test is carried out to see whether the data collection done undeviating observation (in the controller limits) or not. When the data competence test is done to understand which is data has been gotten in sufficient for data dealing out. The quantity of observational data needed for a confidence level of 95% and accuracy level of 5%. The recapitulation of results in uniformity data test and data adequacy test shown in Table 1.

| Job Type      | Uniformity Data | Adequacy Data |
|---------------|-----------------|---------------|
| Wheel Scales  | Uniform         | Sufficient    |
| Pulley        | Uniform         | Sufficient    |
| Sprocket 14T  | Uniform         | Sufficient    |
| Gear          | Uniform         | Sufficient    |
| Sprocket 12T  | Uniform         | Sufficient    |
| Impeller      | Uniform         | Sufficient    |

Based on the table above, it can be seen that the data collection during the observation was uniform and sufficient and it can be used for the next stage.

3.2. Calculation of Standard Time
Standard time is planned after normal time and allowance are known where the proportion of allowance is allowance for rest given to each worker. The result gets from formula 1 and 2 above. The results recapitulation of standard time calculations shown in Table 2.
Table 2. Recap of Standard Time

| Job Type     | M 1 | M 2 | M 3 | M 4 | M 5 |
|--------------|-----|-----|-----|-----|-----|
| Wheel Scales | 15,12 | 23,34 | 38,38 | 63,70 | 15,17 |
| Pulley       | 18,18 | 27,19 | 44,55 | 106,66 | 15,22 |
| Sprocket 14T | 7,67  | 19,61 | 35,31 | 41,21 | 5,63  |
| Gear         | 12,60 | 41,76 | 47,83 | 153,41 | 27,44 |
| Sprocket 12T | 6,51  | 16,82 | 31,96 | 36,07 | 5,50  |
| Impeller     | 13,82 | 28,55 | 44,26 | 60,88 | 10,42 |

3.3. Calculation of Lead Time
Calculation of lead time is influenced by the quantity of machineries owned by the company, production volume or machine and standard time to make a product. Recapitulation of lead time at each job in all work stations can be seen in Table 3.

Table 3. Recapitulation of Lead Time

| Job Type     | M 1       | M 2       | M 3       | M 4       | M 5       |
|--------------|-----------|-----------|-----------|-----------|-----------|
| Wheel Scales | 640,24    | 985,42    | 1228,89   | 2685,55   | 502,84    |
| Pulley       | 308,04    | 458,12    | 576,84    | 1787,73   | 215,21    |
| Sprocket 14T | 209,64    | 527,92    | 726,10    | 1108,97   | 137,68    |
| Gear         | 193,97    | 152,51    | 558,03    | 2311,22   | 333,73    |
| Sprocket 12T | 152,51    | 386,21    | 563,36    | 827,65    | 118,50    |
| Impeller     | 115,54    | 233,44    | 285,58    | 497,01    | 87,53     |

3.4. Actual Scheduling using First Come First Serve (FCFS) Method
Based on the sequence of jobs according to the company method in the form of First Come First Serve (FCFS) where the first order arrives will be done or completed first, then the work order obtained is job 1 - job 2 - job 3 - job 4 - job 5 - job 6 with the resulting makespan value of 202.67 hours.

3.5. Scheduling using Gupta Method
Scheduling with the Gupta method is done by adding up the lead time of closest machines to obtain the minimum value of the minimum time to determine the value of EI and SI. Furthermore, the calculation results are sequenced from jobs have the largest to the smallest value. Recapitulation of the sequence of all jobs with the Gupta method can be seen in Table 4.

Table 4. Scheduling Sequences using Gupta Method

| Job Type     | M 1       | M 2       | M 3       | M 4       | M 5       |
|--------------|-----------|-----------|-----------|-----------|-----------|
| Gear         | 193,97    | 631,47    | 558,03    | 2311,22   | 333,73    |
| Wheel Scales | 640,24    | 985,42    | 1228,89   | 2685,55   | 502,84    |
| Pulley       | 308,04    | 458,12    | 576,84    | 1787,73   | 215,21    |
| Sprocket 14T | 209,64    | 527,92    | 726,10    | 1108,97   | 137,68    |
| Sprocket 12T | 152,51    | 386,21    | 563,36    | 827,65    | 118,50    |
| Impeller     | 115,54    | 233,44    | 285,58    | 497,01    | 87,53     |
The sequence of jobs obtained results in a makespan value of 10.689.13 minutes or equal to 178.15 hours. Gupta method makespan value is shorter when associated to the company authentic method, FCFS method with the order of job 4 - job 1 - job 2 - job 3 - job 5 - job 6 where job 1 is gear.

4. Conclusion
Production scheduling limitations often occur due to delays in products sent to customers due to the long process of product processing. Gupta method is one method can be used to overcome production scheduling problems. The results facilie by this method shows that the time needed to complete the product is shorter than the actual method currently applied by the company, namely the First Come First Serve method with a makespan value of 202.67 hours with the order in which is the product 1-job 2-job 3-job 4-job 5-job 6 when makespan with Gupta method is 178.15 hours with the order of job 4 - job 1 - job 2 - job 3 - job 5 - job 6. Performance with the Gupta method also proved to be good than the actual method of the company with an efficiency index value of 1.17.

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