Scheduling of Flowshop Type Production with Dannenbring Method to Obtain Optimal Results with Observing Waiting Time and Weight of Jobs

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ABSTRACT

Linear programming is a step or process to get maximum results with existing resources or it can be said the process of looking for optimal value. One part of scheduling is production scheduling. Production scheduling is the use of resources that are few but make the most profit. This paper discusses production scheduling using flowshop type production scheduling by taking into account transportation times and work weights. This paper uses the Dannenbring method with the aim of finding the optimal sequence of problems by considering the total production time (makespan) and the average Weighted Mean Flow Time (WMFT). Based on the results of the Dannenbring method, the results of flowshop scheduling are obtained with a total makespan of 75 hours and the WMFT value is 28.87 hours.

Keywords: Linear Programming, Makespan, Weighted Mean Flow Time

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1. INTRODUCTION

Linear programming is a method used to make a decision in solving numerical problems [Pugazhenthi R et al. 2014]. In linear programming, there is one of the most frequently discussed aspects, namely scheduling [González-Neira. E. M. et al. 2017] Scheduling is a step to place resources at a certain time to get the most optimal results. Production scheduling is a step in making decisions in placing the resources in a production process in order to get optimal results so as to generate large amounts of profit [Allahverdi, 2015]. Through scheduling we can determine the amount of use of available resources with existing problems so that we get the most optimal results [Pinedo, 2012]. Production scheduling process itself there are two kinds of scheduling, the scheduling and rescheduling flowshop Jobshop [Garey, MR 1976]. The very basic difference between the two is the process flow on the machine used. In the flowshop scheduling process, it can be said that the flow or plot created is serial or chain flow [Lee, T et al. 2019], while the jobshop type production scheduling is random [TC Edwin Cheng et.al]. Decisions made for processing flow affect work processing time (Ahonen et al. 2016).

In a production process the possibility of scheduling will have several problems in its implementation [Rahmani, D., et al 2014]. This happens because there are several factors such as, on some machines there is maximum capacity in its used [Javad, S 2018], machine availability, the arrival of a new job, a change of priority job, an employee vacancy, and an order cancellation, are common events on production scheduling [Nasr., et al. 2011], [Fahmy, S. A et al. 2008]. [Subramaniam, V., et al. 2005]. Therefore, it is necessary to examine the constraints that cause the production process to not be good. Many studies have examined various kinds of problems in the production process, Lin, TK. et al. 2014] parallel machine scheduling that is not related to the installation time depending on the sequence and the machine and time is ready to minimize the total weighted delay (TWT). [Ahmad. Q. S et al. 2015] Scheduling problems with setting time, transportation time, loading time, loading time minimizes total production costs, total workload and release process. [Ribas I et al. 2015] Discusses the blocking flow shop problem to minimize total flow time. [Gupta et al. 2012] also proves algorithms for scheduling and workflow shop scheduling problems with the time of transport and processing. [Chen, W., et al. 2016] Rescheduling is known as complete rerouting (CR) for an easy manufacturing system. Machines. [Pandian et al. 2010] optimal scheduling for flow-shop scheduling problems involving transportation time, strike time and work weight (constraints of flow-shop scheduling) with 3-machines. [Abdeljaouad, M.A., et al. 2015] job-shop scheduling problem with reverse flows, which is characterized by two work streams that include the same machine in the opposite direction aiming to minimize the maximum completion time of the work (makespan). [Wan, L et al. 2013] the new primary – secondary criteria scheduling problem on identical machines with the intention of is to minimize the total T-time of all machines, where the total completion time of all jobs is to minimize the maximum completion time. [Lin, S] The permutation flowshop scheduling problem with the objective of minimizing total flow time is known as NP-hard problems, events for the two-machine cases.

In general, scheduling aims to obtain efficient use of facilities, time and reduce production costs. The obstacles faced in scheduling are basically related to [2]:

1. Limited available resources.
2. Technology constraints in relation to the sequence of implementation of activities.
3. The deadline for completion is in accordance with the target.
4. The nature and conditions of a job.
The preparation of a scheduling that is solely based on intuition or mere estimates will affect the amount of actual and produced production. In this case the production scheduling will cause idle time and also the idle capacity of the engine used in the production process. This is clearly a factor that can harm the company. Therefore, in this paper the optimal time for each machine and job is considered, and the method used is the Heuristic method where this method sorts the scheduling of types of flowshop production so that it can generate displacement between machines and jobs based on makespan value which is an effective method of resource utilization [Aydilek, A., et al.].

The main objective is to determine the best possible schedule and order of work to minimize the total production time by taking into account the waiting time and work weight. The most common goal for this problem is makespan [Yenisey, M. et al. 2015]. Job evaluation and differentiation are crucial in scheduling. Since jobs can be represented by vectors of processing times, the average, standard deviation, and skewness of job processing times can be defined as the moments of their probability distribution. The first and the second moments of processing times are effective in sorting jobs (Dong et al., 2008), however they are not yet optimized to characterize and differentiate distributions of similar jobs.

2. MATERIAL AND METHOD

2.1. Flowshop Scheduling

The flowshop scheduling model is an effective tool for management that can be used to model multiple services and has excellent adaptability with most real-world problems [Ebrahimi, M., et al. 2014]. Flowshop configuration are commonplace in manufacturing setting where a set of jobs $N = \{1, 2, \ldots, n\}$ are processed by a set of machines $M = \{1, 2, \ldots, m\}$. Each job goes through the machines in the same technological order, i.e. it starts at machine 1, the goes to machine 2, up to machine $m$ [Rossit, D. A., et all 2018]. In the Flowshop problem, it is assumed that the jobs have to pass through all stages in the same order and there are at least one stage having multiple machines. Additionally, one machine can only process one job at a time. As to one single job, it can be processed by only one machine at a time. Preemption of processing is not allowed [Cui, Z., et al. 2015].

![Figure 1. Flowshop Workflow](image-url)
Scheduling flowshop divided into 2 flowshop pure and general flowshop. Scheduling pure flowshop is a production planning problem with \( n \) jobs (of items, tasks, etc.) that must be processed in the same order on each machine \( m \). Examples of scheduling pure flowshop are cake making, where each production must go through a machine in sequence.

General flowshop is a production plan that must be in the same order and does not have to go through every machine. Each job has a different processing time for different machines. Examples of general flowshop scheduling such as clothing production, not all clothing produced produces perfect results, there are some clothes that may not be perfect in the production process, for example when through sewing machines, the clothes are good, but when entering a screen printing machine, there may be some not good, poor clothes can be reproduced again and do not need to go through a sewing machine, but directly through a screen printing machine.

In essence, public flowshop does not have to go through all the machines in the production flow.

Some characteristics of flowshop scheduling include [Li, W et al. 2015]:

1. is available machine \( m \) and jobs \( n \).
2. Each job consists of operation \( m \) and each operation requires a different machine.
3. Job \( n \) th selected in the same order as machine \( m \).
4. The processing time of the job \( i \) th engine \( j \) th is denoted by. \( t_q (i = 1,2,\ldots,n \) and \( j = 1,2,\ldots,m) \)
5. A schedule is arranged in the form of a job sequence, which will fulfill a specific goal. The purpose often used is to minimize makespan.

2. 2. Processing Time

Scheduling can be said to be optimal if you get the most results by using the most minimal resources. The most expensive resource used in a scheduling or production process is time. A production process can be said to be optimal if the time used for production is small. That is, the amount of time used for a production must be inversely proportional to the results achieved so that a production process can be said to be optimal. The time passed in a production process has several aspects, namely the start time, the time of transfer between machines, waiting time, and time to finish. As for what is said to be breaktime or pause time, that is the time in the event of an error or obstacle that makes the production process stop. So, it can be concluded that the time passed by a production is the difference between the production time and the time when the production begins. In order to be able to reduce the time used to a little possible, a company must be able to schedule a production process taking into account the time of transfer between machines and waiting times. In scheduling production types of flowshop the time used can be used up to a little possible by considering several things. So, we can sort the scheduling of types of flowshop production so that it can produce the transfer time between machines and the waiting time to be a little. There are several methods that are generally used to get the most optimal results using the least amount of time.

2. 3. Transportation Time

Transportation time \( t(t) \) is the time of transfer that occurs on one machine to another or in other words waiting time (waiting time) or no activity occurs while the engine is working.
Time of transportation is one of the things that need to be considered, because it involves the production process. In other words, transportation time is one of the capacity constraints which means the different capacities of each machine in one production process. This is a consideration in measuring the performance of production scheduling, namely flowtime. Generally there are several jobs that must be completed, each of which has a different processing time, therefore there is an average of each processing time in each job, namely Mean Flow Time (MFT), which becomes the scheduling performance measurement criteria in this thesis. This criterion shows the average time spent on each job on the factory floor. Flowtime is the difference between the completion time and the start time for each job $i$.

$$ F = \frac{1}{n} \sum_{i=1}^{n} F_i $$  

(1)

$n$ = the number of parts produced

2. 4. Weight of Jobs

Weight of Jobs is a value determined by priority rules, so a high-weight job is generally completed earlier than a low-weight job. Even the priority rules used are a company policy regarding production scheduling. Shortest Processing Time (SPT) is a method that prioritizes the completion of the production process based on the fastest processing time.

Weight of Jobs is one thing that needs to be considered, because it involves the production process. In other words, work weight is one of managerial constraint, which means an obstacle that occurs due to incompatibility of company policy with an operated production system. This is a consideration in measuring the performance of production scheduling, namely the flowtime that has been weighted. Generally there are several jobs that must be completed, each of which has a different processing time after being weighted according to the priority rules of the company, therefore there is an average of each processing time in each job that has been weighted namely Weight Mean Flow Time (WMFT), which became the scheduling performance measurement criteria in this paper [Y. Liu, et al. 2014]. Definition of weight mean flowtime is similar to the mean flowtime, but considers the priority of work for each job in its calculation.

$$ \bar{F_w} = \frac{\sum_{i=1}^{n} W_i \cdot F_i}{\sum_{i=1}^{n} W_i} $$  

(2)

2. 5. Johnson Rules

Johnson's rule is a technique to minimize processing time in a production. This Johnson rule is used for production that uses more than 2 machines. That is, a product passes several operations from start to finish [Dang. F et al. 2018].

However, to be able to use Johnson's rules, several conditions must be met, including:

1. The time of production or operation on the certain job or order must be known and constant or fixed.
2. Processing time does not depend on the order.
3. Job priority rules are not taken into account.
4. Every job must go through the same processes or operations.

The use of this Johnson rule is to reduce the pause time or production waiting time on one machine to the next. To get the order using Johnson rules are as follows [Conway, RW et all 1967]:
1. Sort all orders based on production time, the order made is from the job with the least production time until the job with the longest production time.
2. If there are two or more production machines.
3. Job that has the same production time on a machine, then jobs that have longer time on the next machine will be produced first.
4. The saving time is the difference in time before using Johnson's rules after using Johnson's rules in the production process.

2.6. The Dannenbring Method

The Dannenbring method is a method developed or derived from the Johnson method (1954). This method is able to solve scheduling problems involving more than two (2) machines [Panneerselvan 1999].

Problems that involve more than two machines are converted into a recapitulation table consisting of two $Pi$ values, i.e. $Pi_1$ and $Pi_2$, which is the job $i$th processing time in the $n$ th engine. The following equation shows the formula of the Dannenbring method [Dannenbring, D. G 1977].

$$T_{j1} = \sum_{i=1}^{m} (m - i + 1) * t_{ij}$$

(3)

from the equations 3 above, the time for the first engine and the processing time. After that the job scheduled with Johnson's algorithm, using parameters is $T_{j1}$ the process time on machine 1 and for the second machine will be obtained

$$T_{j2} = \sum_{i=1}^{m} i * t_{ij}$$

(4)

and is $T_{j2}$ the processing time on machine 2 [Wang, F. Et all 2011].

The Local Search Mechanism design is obtained based on the values in the table $Pi_1$ and $Pi_2$, the results of the study find six local search categories for the data of job processing time $i$ for machines 1 and 2, the first category is with [Dannenbring, D.G. 1977]:
1. Positioning the minimum value in table 1 as the last job sequence, the process begins by looking for the minimum value in the column $Pi_2$;
2. Positioning the minimum value in table 1 as the last job sequence, the process begins by looking for the minimum value in the column $Pi_1$;
3. Positioning the minimum value at $Pi_1$ the beginning and the minimum value at $Pi_2$ the end of the sequence, the process starts from $Pi_1$;
4. Positioning the minimum value at $P_{i_1}$ the beginning and the minimum value at $P_{i_2}$ the end of the sequence, the process starts from $P_{i_1}$;
5. Positioning the minimum value in the initial order, the process starts from $P_{i_1}$;
6. Positioning the minimum value in the initial sequence, the process starts from $P_{i_2}$.

3. RESULT AND DISCUSSION

The first step in the Dannenbring method is to get a table of expectation values for each job.

**Table 1. Data Scheduling Production of Case Examples.**

<table>
<thead>
<tr>
<th>Job</th>
<th>A</th>
<th>$t_{a\to b}$</th>
<th>B</th>
<th>$t_{b\to c}$</th>
<th>C</th>
<th>$W_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

$A_i$: Process time on machine A  
$B_i$: Process time on machine B  
$C_i$: Process time on machine C  
$A_i':$ Expectation of the $i$-th job process time on machine A  
$B_i':$ Expectation of the $i$-th job process time on machine B  
$C_i':$ Expectation of the $i$-th job process time on machine C  
$\tau_s$: The transport time of the $i$-th job moves to the next machine ($s = 1, \ldots m - 2$)

For the next step, the value will be calculated $A_i', B_i', and C_i'$,

$A_i' = A + t_{a\to b}$

$B_i' = B + t_{b\to c}$

$C_i' = C$
Table 2. Processing Time on Fictive Machines.

<table>
<thead>
<tr>
<th>Job</th>
<th>$A'$</th>
<th>$B'$</th>
<th>$C'$</th>
<th>$W_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>11</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>11</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>12</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>7</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

After obtaining a value of $A_i'$, $B_i'$, and $C_i'$ calculated value from $A_i''$, $B_i''$, and $C_i''$

$$A_i' = \frac{A_i}{W_i} \quad B_i'' = \frac{B_i'}{W_i} \quad C_i'' = \frac{C_i'}{W_i}$$

Table 3. Process Time that has been weighted on a Fictitious Machine

<table>
<thead>
<tr>
<th>Job</th>
<th>$A''$</th>
<th>$B''$</th>
<th>$C''$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,5</td>
<td>2,75</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3,67</td>
<td>3,67</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5,5</td>
<td>4</td>
<td>3,5</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>2,4</td>
<td>1,4</td>
<td>1,8</td>
</tr>
</tbody>
</table>

The next step is to find the value $Pi_1$ and $Pi_2$

Table 4. Job Processing Time to $Pi_1$ and $Pi_2$

<table>
<thead>
<tr>
<th>Job</th>
<th>$Pi_1$</th>
<th>$Pi_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21,75</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>28,02</td>
<td>17,01</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>24</td>
</tr>
</tbody>
</table>
From the calculation of the values of $P_i_1$ and $P_i_2$, the optimal order from the Dannenbring method is obtained $4-3-2-1-5$

Table 5. Makespan Value

<table>
<thead>
<tr>
<th>Job</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>$w_i$</th>
<th>$F_i$</th>
<th>$w_i . F_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0–13</td>
<td>13–25</td>
<td>25–30</td>
<td>1</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>13–24</td>
<td>25–33</td>
<td>33–40</td>
<td>2</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>2</td>
<td>24–35</td>
<td>35–46</td>
<td>46–52</td>
<td>3</td>
<td>28</td>
<td>84</td>
</tr>
<tr>
<td>1</td>
<td>35–45</td>
<td>46–57</td>
<td>57–65</td>
<td>4</td>
<td>30</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>45–57</td>
<td>57–64</td>
<td>65–74</td>
<td>5</td>
<td>29</td>
<td>145</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>15</th>
<th>144</th>
<th>433</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFT</td>
<td></td>
<td></td>
<td>28.8</td>
</tr>
<tr>
<td>WMFT</td>
<td></td>
<td></td>
<td>28.867</td>
</tr>
</tbody>
</table>

The result of makespan from the optimal sequence is obtained from $4-3-2-1-5$ is 75 calculated by weighted mean flowtime using the formula

$$F = \sum_{i=1}^{n} W_i . F_i$$

$$F = \frac{30 + 54 + 84 + 120 + 145}{15} = \frac{433}{15} = 28.867 \text{ jam}$$

4. CONCLUSION

From the discussion above we see that the Dannenbring method is able to solve flowshop scheduling problems with the optimal sequence $3-2-4-1-5$ of the total makespan of 75 hours. Then, from Table 3 we see flow time and weighted flow time of each jobs. So, in the end we get the value of weighted mean flow time of 28.867 hours. In this study the most optimal
value is seen from the makespan value. But the value of weighted mean flow time is affected by the mean flow time multiplied by the weight value of each job. Thus, it is not possible to find results where the smallest makespan does not have a small weighted mean flow time.

References


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