Branch and Bound Method to Overcome Delay Delivery Order in Flow Shop Scheduling Problem

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Abstract. Leather industry is one of the industrial sector in Indonesia. Leathercraft industry is one of the industrial sector which concerning to improve the national economic growth of Indonesia. PT Mandiri Jogja International (PT M. Joint) has a problem in late completion production time which caused delay delivery order. So that this company need an evaluation on job scheduling production system which have a smallest total completion production time (makespan). This research is to make a new sequencing scheduling using Branch and Bound method, which has the smallest total completion production time (makespan). Branch and bound is one of the algorithm used to make a new sequencing scheduling. The results showed that scheduling with the actual method applied in the company by sequencing 4-3-5-1-2 has makespan score 13630.68 seconds or 3.79 hours. The scheduling using Branch and Bound method by sequencing 2-1-3-4-5 and 2-1-4-3-5 have a makespan score 12954.46 seconds or 3.60 hours. Branch and Bound method has a makespan 0.19 hours small than actually method at the company. Therefore, branch and bound method is used to make a new sequencing scheduling to overcome delay delivery order at PT M. Joint Exclusive Leahtercraft.

1. Introduction
The industry is one of the sectors that the government concerning to improve the national economic growth of Indonesia. The industry is related to the economic sector which productive activities is processing raw materials into semi-finished goods or finished goods (manufacturing). The development of the industry is increasingly impressive when viewed from its performance in terms of revenue, both in terms of the value of the products it produces and its contribution in terms of revenue. Leather bag industry is one of the industrial sector in Indonesia. The leather industry began to develop in Indonesia since the 1970s. Leather Industry is one of entrepreneurship that contributed as much as 7.38% to national Gross Domestic Product (GDP). This has proven to be able to increase national economic growth in 2018 from 5.2% to 5.4% [1].

Leather Bag is one of the Creative Industry products that utilizes natural skin resources as its main ingredient. Utilization of Cowhide for human interests goes in the direction of the development of human civilization. From the overall byproducts of slaughtered cattle, the skin is the product that has the highest economic value. Weight of skin in cows, goats and buffalo has a range of 7-10% of body weight. Economically leather has a price ranging from 10-15% of the price of livestock. Leather bags are made from the main ingredients Leather that goes through a smooth tanning process.

With the implementation of the free trade system, it has forced economic actors from the central level to the regions to be able to compete with other producers, especially outside producers. The role
of the Indonesian government itself in free trade is to encourage regional economic development to continue to prioritize Micro, Small and Medium Enterprises (MSMEs) which are considered to have a major role in job creation and national economic growth [2].

PT Mandiri Jogja International is one of the companies of creative industry leather bags. This company has products that are sold under different brands according to their market share. Namely the SACCO brand to meet the Canada & Europe market, Henk Berg for the Australian market and Bucini for the Indonesian market. SACCO products have the largest number of orders compared to other products. As a leather bag manufacturing industry, PT M. Joint has a problem in late completion of work. where one of the causes of the delay in completion of the work is because the production process is too long so that it slows down the product finishing process. In a production system, the sequences of job dispatching have several effects such as higher total production time, longer completion time, and higher tardiness [3].

There is considerable amount of literature on the overcome delay delivery order. Scheduling problems integrated with preventive maintenance [4]. Scheduling is the process of organizing, selecting and timing of the use of existing resources to produce output as expected within the expected time too [5]. Branch and bound is one method in preparing production scheduling using branching algorithms and lower limits. This method succeeds in providing a sequence of product work completion schedules with a faster total production time. Therefore, this research was conducted with the theme of evaluating production scheduling using the branch and bound method to overcome product delivery delays. The basic scheduling decision is to define an ordering between all those operations which have to be processed on the same machine [6]. In this paper, branch and bound method is used to overcome delay delivery order in PT M. Joint Exclusive Leathercraft by make a sequencing job with smallest makespan. This method is one of principle of scheduling to allocation of resources overtime to perform minimize of risk [7].

2. Methodology

In this study, data collection was conducted at PT Mandiri Jogja International (PT M. Joint) in the village of Klodangan RT 02 RW 26 Sendangtirto, Berbah, Sleman, Yogyakarta on SACCO products with types 87136, 87186, 87265, 87323 and 87529 which has the most orders this year. Data gathering was carried out through study time measurement studies. Work time obtained is then processed to produce standard time work. The standard time is used to make a scheduling by actually method in the company and the Branch and Bound method. The parameter used to measure the performance of a scheduling is makespan [8]. So that the best scheduling is the method that produces the smallest makespan. The discussion of the result analysis is a comparison of the makespan of the actual method in the company with the branch and bound method. And the last is make a conclusion based on research study. The step of research was shown as following figure:
2.1. Work time measurement
One of the criteria for work measurement is time study [9]. Work measurement in question is a measurement of standard time or standard time. General understanding of work measurement is an activity to determine the time needed by an operator (who has average and trained skills) in carrying out work activities in normal working conditions and tempo. Standard time can be used as a basis for other analyzes. Measurement of working time with stop hours is done by preliminary measurements first. The preliminary measurement data then tests the adequacy and uniformity of the data. The data has met the adequacy test and uniformity of data is then determined by the average value and rating factor to determine the normal time of work. Normal time is added to the allowance or allowance of workers and is set as standard time.

2.2. Branch and bound algorithm
The production process at FMC consists of 2 stages, namely the machining stage with several parallel machine fixed and the assembly stage with several robot assembly machines [10]. Production scheduling which is commonly applied by FMC is not always a permutation, so in his research it is proposed to arrange permutation schedules and then look for a better non-permutation schedule near the permutation location enumeratively using Branch and Bound algorithm. The results of numerical experiments show that the Branch and Bound algorithm efficiently provides optimal and near optimal scheduling with a high degree of accuracy, such as a relative error of less than 0.2% and a maximum relative error of 3%.

In work conducting computational studies, the use of Branch and Bound algorithms to complete batch scheduling in parallel on jobs that have different numbers of units, processing times and release
times [11]. Ozturk et al compared the Branch and Bound method with the mix integer programming method in production problems. The results of the computational study show that the Branch and Bound method is more efficient than the mix integer programming method in terms of the time to complete the work (make-span) to get the optimal solution. Thus, the method is available to be applied.

The Branch and Bound algorithm is "A useful method for solving many combinatorial problems" [12], which is a good method for solving combination problems. As an example of a branching procedure can be explained if P is declared as a single-machine scheduling problem with n jobs, the problem P (0) can be branched into n subproblems, namely P (1), P (2), ..., P (n). P (1) is scheduling job 1 in the initial order. P (2) is scheduling job 2 in second, and so on. Then, the subproblem will be broken down into several new subproblems. For example, P (2) is branched into P (12), P (32), ..., P (n2). The steps for scheduling the Branch and Bound method are [13]:

- List all jobs that will be done and the completion time on each machine
- Calculate the partial order before there is a job
- In the i partial job sequence, calculate q1 to qn
- Calculate the amount of the lower bound li until ln
- Compare all li values, select which has the maximum value to be used as the LB partial sequence.
- Comparing all LB values from existing job partial sequences, select who has the minimum value to be scheduled beforehand, then the job is eliminated
- Repeat the above steps until all jobs are scheduled

Algorithm:

\[
\begin{align*}
L1 &= q(Jr, 1) + \sum A_i + \min Jr'(B_i + C_i) \\
L2 &= q(Jr, 2) + \sum B_i + \min Jr'(C_i) \\
L3 &= q(Jr, 3) + \sum C_i
\end{align*}
\]

as for the values, the lower limit is:

\[LB(s) = \max \{L1, L2, L3\}\] (4)

Where

LB (s) / l = Lower bound (lowest makespan)

A_i = Processing time for job i on the machine

B_i = Processing time for job i on machine B

C_i = Processing time for job i on machine C

Jr = Partial schedule or schedule jobs

Jr' = The set of remaining (n-r) jobs

q = Completion time of the job

3. Result and Discussion

Scheduling is an overall manufacturing order / work done on several machines [14]. Scheduling is a good measurement for aggregate planning. The actual orders at this stage will first be assigned to certain resources (facilities, workers and equipment), then work will be sorted at each processing center so that optimal capacity utilization is achieved. In this scheduling, requests for certain products (types and quantities) of MPS will be assigned to certain processing centers for daily periods. In this paper, scheduling at PT Mandiri Joga International had a problem caused delay delivery order. Therefore, to overcome this problem is by compare between actually scheduling with used branch and bound method.

3.1. Work time measurement

Each product article is stated as a job represented by numbers 1 through 5. Each job is carried out through 6 work stations that are declared as machines 1 to machines 6. The results of data collection
on the five types of SACCO products on each machine produce the standard time presented in the following table:

Table 1. Work time measurement each machine

| Product | Job | Machine (second) |
|---------|-----|-----------------|
|         |     | M1 | M2 | M3 | M4 | M5 | M6 |
| 87136   | 1   | 166,60 | 93,43 | 2500,31 | 1722,56 | 259,76 | 262,77 |
| 87186   | 2   | 85,37 | 66,99 | 2261,37 | 1571,16 | 131,30 | 245,52 |
| 87265   | 3   | 148,88 | 105,63 | 2845,01 | 1442,01 | 246,68 | 240,02 |
| 87323   | 4   | 265,89 | 122,41 | 1843,45 | 1436,12 | 154,70 | 220,35 |
| 87529   | 5   | 182,50 | 137,36 | 1844,26 | 1053,77 | 217,34 | 236,59 |

PT M. Joint Exclusive Leathercraft in carrying out production activities prioritizes difficult products first. Based on the five products studied, among others 87136, 87186, 87265, 87323 and 87529, PT M. Joint carried out the production process in the order 87323, 87265, 87529, 87136 and 87186 or 4-3-5-1-2. Calculation of total production time or makespan presented in the following table:

Table 2. Makespan at machine 1-3 to sequencing 4-3-5-1-2

| Job | Sequencing | \( t_{(i,1)} \) | \( t_{(i,2)} \) | \( t_{(i,3)} \) | \( t_{(i,4)} \) | \( t_{(i,5)} \) | \( t_{(i,6)} \) |
|-----|------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1   | 4          | 26,47          | 265,89         | 265,89         | 132,1          | 2845,01        | 388,3          |
| 2   | 3          | 182,50         | 105,63         | 26,47          | 0              | 2845,01        | 0              |
| 3   | 5          | 166,60         | 93,43          | 29,24          | 122,67         | 2500,31        | 0              |
| 4   | 1          | 85,37          | 66,99          | 0              | 66,99          | 2261,37        | 0              |
| 5   | 2          | 1436,12        | 1408,99        | 2850,9         | 246,68         | 2696,2         | 2942,88        |
|     | Total      | 849,24         | 525,82         | 398,47         | 11294,4        | 388,3          | 11682,7        |

Table 3. Makespan at machine 4-5 to sequencing 4-3-5-1-2

| Job | Sequencing | \( t_{(i,4)} \) | \( t_{(i,5)} \) | \( t_{(i,6)} \) | \( t_{(i,7)} \) | \( t_{(i,8)} \) | \( t_{(i,9)} \) |
|-----|------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1   | 4          | 1436,12        | 2231,75        | 3667,87        | 154,7          | 3667,87        | 3822,57        |
| 2   | 3          | 1442,01        | 1408,99        | 2850,9         | 246,68         | 2696,2         | 2942,88        |
| 3   | 5          | 1053,77        | 402,25         | 1456,02        | 217,34         | 1209,34        | 1426,68        |
| 4   | 1          | 1722,56        | 1446,54        | 3169,1         | 259,76         | 2951,76        | 3211,52        |
| 5   | 2          | 1571,16        | 538,81         | 2109,97        | 131,3          | 1850,21        | 1981,51        |
|     | Total      | 7225,62        | 6028,24        | 13253,9        | 1009,78        | 12375,38       | 13385,2        |

Table 4. Makespan at machine 6 to sequencing 4-3-5-1-2

| Job | Sequencing | \( t_{(i,6)} \) | \( t_{(i,7)} \) | \( t_{(i,8)} \) | \( t_{(i,9)} \) | \( t_{(i,10)} \) | \( t_{(i,11)} \) |
|-----|------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1   | 4          | 220,35         | 3822,57        | 4042,92        |                 |                 |                 |
| 2   | 3          | 240,02         | 2722,53        | 2962,55        |                 |                 |                 |
| 3   | 5          | 236,59         | 1186,66        | 1423,25        |                 |                 |                 |
| 4   | 1          | 262,77         | 2974,93        | 3237,7         |                 |                 |                 |
| 5   | 2          | 245,52         | 1718,74        | 1964,26        |                 |                 |                 |
|     | Total      | 1205,25        | 12425,4        | 13630,68       |                 |                 |                 |

Based on table 4 above, obtained the value of makespan from scheduling using the actual method in the company with a 4-3-5-1-2 has a total completion production time (makespan) 13630.68 seconds or 3.79 hours. The chart from this sequencing scheduling shown as following figure:
3.2. Branch and bound algorithm

Achievement of goals begins by creating a branch and bound algorithm. Data used to produce alternatives so that the lower bound is obtained each alternative and the alternative that has the lowest lower bound is chosen to be scheduled. Calculations are repeated until all jobs have been completely scheduled. According to Hu et. al. for the branch and bound algorithm in the case of resource constrained project scheduling problem, the arrangement of spatial areas must be determined based on existing nodes and branching [15]. Pinto said, each branch forms a combination of work into a partial combination sub-set, which is composed of several work stations [16].

In scheduling production using the Branch and Bound method, branching begins by developing a node before there is a job. Branching results that have the lowest total production time are set as lower bound and will be determined as nodes to be branched back. The branching process starts in the first iteration before the job scheduled. In the first iteration, job 2 was chosen as the node to be branched again. In the second iteration, job 2 is combined into nodes 21, 23, 24 and 25, then combination 21 was chosen as the node to be branched again. In the third iteration, job 21 was combined into 213, 214 and 215. Then a combination of 213 and 214 was chosen as the node to be branched again. In the fourth iteration, node 213 was branched into 2134 and 2135, while node 214 was branched into 2143 and 2145.

After the branching method is done as many as 4 iterations to produce the shortest work completion time. The results of the branching in the 4th iteration are as follows:

\[
\text{LB(2134)=max} \begin{cases} 
666.74+182.50+3849.32=4338.56 \\
789.15+137.36+3351.96=4278.47 \\
9602.50+1844.26+1507.70=12954.46 \\
11038.62+1053.77+453.93=12546.32 \\
11193.32+217.34+236.59=11647.25 \\
11413.67+236.59=11650.26 
\end{cases} =12954.46
\]

\[
\text{LB(2135)=max} \begin{cases} 
583.35+265.89+3777.03=4626.27 \\
720.71+122.41+3654.62=4497.74 \\
960.31+1843.45+1811.17=13257.93 \\
10657.08+1436.12+375.05=12468.25 \\
10874.42+154.70+220.35=11249.47 \\
11111.01+220.35=11331.36 
\end{cases} =13257.93
\]

\[
\text{LB(2143)=max} \begin{cases} 
666.74+182.50+3489.32=4338.56 \\
772.37+137.36+3351.96=4261.69 \\
960.31+1843.45+1811.17=13257.93 \\
11044.51+1053.77+453.93=12552.21 \\
11291.19+217.34+236.59=11745.12 \\
11531.21+236.59=11767.80 
\end{cases} =12954.46
\]
Based on the 4 branches that have been carried out, branches that have the smallest make-span value are selected, namely lower bound or LB (2143) and LB (2134) branches with a score of makespan 12954.46 seconds or 3.60 hours. Thus, the sequencing scheduling used Branch and Bound method is 2-1-4-3-5 and 2-1-3-4-5. The gantt chart of this sequencing was shown as following figure:

Figure 3. Gantt chart of 2-1-3-4-5 sequencing

Figure 4. Gantt chart of 2-1-4-3-5 sequencing

In the production planning system, the sequencing and scheduling plays an important role in order to ensure the effectiveness and efficiency of production. The more complex in a production system, the more needed a good production scheduling. Based on the scheduling principle carried out by the company, the order in which the products are processed is 4-3-5-1-2 with makespan score is 13630.68 seconds or 3.79 hours. Although scheduling using the Branch and Bound method have a combination sequencing 2-1-3-4-5, 2-1-4-3-5 with makespan score is 12954.46 seconds or 3.60 hours. Scheduling using Branch and Bound method has smallest makespan, Therefore this method is used to be conclusion.

The results of the branch and bound method are the sequence of workmanship and loading job on each machine. The results of the Branch and Bound method are able to save 676.22 seconds of processing time or 0.19 hours faster than the methods applied by the company. Thus, through the application of this method in the company, it can save time in the production process. Therefore the company is able to speed up production time. Thus, the problems at PT Mandiri Jogja International can be resolved. PT M. Joint Exclusive Leathercraft could send its products faster than before. So that delay delivery order in company could be overcome.

4. Conclusion
Leathercraft industry is one of the industrial sector which concerning to improve the national economic growth of Indonesia. PT Mandiri Jogja International (PT M. Joint) has a problem in late completion production time which caused delay delivery order. So that this company need an evaluation on job scheduling production system which have a smallest total completion production time (makespan). Branch and bound is algorithm was used to make a new sequencing scheduling. The results showed that scheduling with the actual method applied in the company has makespan score
13630.68 seconds or 3.79 hours. The scheduling using Branch and Bound method has a makespan score 12954.46 seconds or 3.60 hours. This method has a makespan 0.19 hours small than actually method the company. Therefore, branch and bound method is used to make a sequencing scheduling to overcome delay delivery order at PT M. Joint Exclusive Leathercraft.

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