Analysis of textile dye production scheduling using FCFS, CDS and Heuristic Pour methods

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Abstract. PT. X is a company engaged in the chemical industry that produces various types of textile dyes for several garment companies in Indonesia and abroad. The manufacture of various dye textiles has a different processing time because it is influenced by the quality and parameters of each product. The production scheduling system used by the company is First Come First Served (FCFS). Companies often experience delays in the timely delivery of orders due to the production scheduling system that is used by the company was not optimal. This research was conducted to schedule a sequence of textile dye processing in PT. X by using the FCFS, Campbell Dudek Smith (CDS) and Heuristic Pour to get shorter makespan and minimize delivery delays. The results of research at PT.X showed that the scheduling method which had the fastest makespan was the Heuristic Pour scheduling method with a total makespan of 562.4 hours (23 days) and could save time by 47.96 hours or 7.86% compared to the FCFS method.

Keywords: production scheduling methods, makespan, textile dye, delivery delay

1. Introduction

Production activities are the main activities that must be carried out by companies engaged in manufacturing. Companies that implement a make to order system will produce goods according to customer orders. Therefore, companies must try to complete the production process in accordance with the specified deadline in order to minimize delivery delays. Then we need an appropriate sequence of workmanship to produce the fastest time to complete the job. Scheduling is an effort to manage activities or work with the aim of achieving efficient use of facilities, time and costs.

PT. X is a company engaged in the chemical industry that produces various types of textile dyes for several garment companies in Indonesia and abroad. The company produces based on incoming orders (make to order). The company produces 20 families of textile coloring products with more than 300 variants of textile dyes. Each variant has the same sequence of production processes which can result in idle time on materials and machines which greatly affect the product finishing time. The method used by companies to schedule their products was First Come First Served (FCFS) where first-time orders would be prioritized. Based on the data obtained, it was known that in February 2019, PT. X experienced delays in sending orders from three garment companies in Indonesia. The delay could be caused by the scheduling method used which was not quite right because the FCFS method does not pay attention to the production process time and due date of each order. Table 1 shows the data of shipping delays experienced by PT. X.
This research was conducted to make a production schedule with the right method so that the sequence of workmanship was obtained with the amount of time needed to complete all orders to become shorter. In this research, the scheduling method used was the Heuristic Pour algorithm and Campbell Dudek Smith (CDS).

2. Methods
Scheduling can be interpreted as allocating a number of resources to perform a number of tasks or operations in a certain period of time and is a decision making process whose role is very important in the manufacturing and service industries [1]. This study uses 3 production scheduling methods, namely:

- First Come First Served (FCFS) [2]. FCFS is a method where orders that come first will be prioritized to be done. This method was used by PT. X to schedule orders from consumers.
- Campbel Dudek Smith (CDS) [3]. This method solves the problem of n jobs on m machines into two groups, then sequences jobs on the two machines using the Johnson algorithm. After obtaining as many m-1 alternative job sequences, then the order with the smallest processing time will be chosen. The Johnson algorithm rule was developed for n jobs that are done on two machines in sequence. In the calculation of the CDS algorithm, we can use the following formula:

\[ t^*_{i,1} = \sum_{k=1}^{k} t_{i,k} \]  
\[ t^*_{i,2} = \sum_{k=1}^{k} t_{i,m-k+1} \]  

The steps for scheduling with the CDS algorithm are as follows:
1. Determine the number of iterations, i.e. the number of work center minus 1 or \( K = m - 1 \).
2. Take the first scheduling (\( K = 1 \)). For all jobs, look for the minimum value of \( t^*_{i,j} \) which is the processing time on the first and second machines, where \( t^*_{i,1} = t_{i,1} \) and \( t^*_{i,2} = t_{i,2} \). Do it also for the next iteration.
3. Perform Johnson's rules. If the minimum time is obtained on the first machine \( (t_{i,1}) \) place the task at the beginning of the scheduling sequence and if the minimum time is obtained on the second machine \( (t_{i,2}) \), the task is placed at the end of the scheduling sequence.
4. Remove the tasks from the list and arrange them in the form of a scheduling sequence. If there are no jobs left, the scheduling is complete. Thus, the processing time of the two machines namely the first machine \( (t^*_{i,1}) \) and the second machine \( (t^*_{i,2}) \) on the K-scheduling has been completed (see formulas 1 and 2).
5. The calculation is continued based on the next task then calculates the makespan.
6. Continue to do these steps until we get the order of assignment with the smallest makespan.

- Heuristic Pour Algorithm [4]. This method was developed by Hamid Davoud Pour (2001) in completing flow shop scheduling with the aim of minimizing makespan based on a combination approach. The following notation is used:
  * \( P_{ij} \) : the processing time of job \( i \) on machine \( j \).
  * \( C_{ij} \) : the time span between when job \( i \) on machine \( j \) starts \( (t = 0) \) until the job is finished.
  * \( \sum C_i \) : sum of completion time for job \( i \) on all machines.

| Table 1. Shipping delay in February 2019 |
|-----------------------------------------|
| Shipping delay | Percentage |
|----------------|------------|
| PT A 3,005 kg | 37%        |
| PT B 3,110 kg | 38%        |
| PT C 2,015 kg | 25%        |
• $F_{max}$: the time span between when the work can begin until the work is finished (makespan).

The steps for scheduling the Heuristic Pour algorithm are as follows:

1. Choose job 1 as the first sequence while in the work order so that job 1’s processing time on all machines is considered zero.
2. Placing other jobs (other than those that have been selected as the first order, that is job 1) in the next sequence.
3. Select the smallest processing time for each machine.
4. Increase completion time for each $P_{ij}$ by increasing processing time rules, namely by adding cumulative processing time from the smallest to the largest in each $P_{ij}$.
5. Calculates the sum of completion time ($\sum C_i$) for each existing job.
6. Sort $\sum C_i$ with the increasing order rule (i.e. ordering from the smallest to the largest) to be placed in the order after the job that has been selected for the first order (ie job 1).
7. After obtaining a sequence where job 1 is the first order, then calculate the $F_{max}$ from the sequence.
8. Repeat steps 1-7 for each existing job that will be placed first in the sequence of job execution until the minimum $F_{max}$ value is obtained.
9. Repeat steps 1-8 for the job that will occupy the next position that is in the second, third, and so on after the job is selected for the first position with a minimum $F_{max}$ value.

The next step was calculated performance parameters. In the research of production scheduling, there are several performance parameters used to determine better methods, namely Efficiency Index (EI) which is a comparison between the proposed scheduling method and the method used by the company, formulated as follows [2]:

$$ EI = \frac{F_{max \text{ method used by the company}}}{F_{max \text{ proposed scheduling method}}} $$

If $EI = 1$, then both methods have the same performance, if $EI < 1$, the proposed scheduling method has poor performance compared to the method used by the company.

### 3. Result and Discussion

#### 3.1. Customer request data

Data on customer requests for May 2019 along with due dates can be seen in Table 2 while data on machines used for the production of textile dyes can be seen in Table 3.

| Product Code        | Colour Code | Demand (kg) | Due Date (days) | Purchase Order Date |
|---------------------|-------------|-------------|-----------------|---------------------|
| Terasil Brown 2RFL  | YROH        | 15,500      | 20              | 23/04/2019          |
| Teratop Black HL-BL | YHAL        | 17,000      | 20              | 24/04/2019          |
| Teratop Black LF-01 | YHAL        | 24,000      | 20              | 25/04/2019          |
| Teratop Black HL-NF-01 | YHAL   | 8,500       | 20              | 29/04/2019          |
| Terasil Blue WW-2GS | YROH        | 10,500      | 20              | 29/04/2019          |
| Teratop Blue HL-B   | YHAL        | 25,000      | 20              | 29/04/2019          |
| Novasol Blue RS MD  | YFER        | 30,000      | 20              | 30/04/2019          |
| Terasil Orange GLN  | YROH        | 12,000      | 20              | 02/05/2019          |
| Terasil Orange HLNF | YROH        | 28,000      | 20              | 03/05/2019          |
| Terasil Red W-4BS   | YROH        | 49,000      | 20              | 03/05/2019          |
Table 3. Name and capacity of machines in each work station

| Machine Station | Amount (unit) | Production Capacity/Machine (kg) | Total Capacity Machine (kg) |
|-----------------|--------------|----------------------------------|-----------------------------|
| Pasting Material | R10 (M1)     | 12,000                           | 12,000                      |
| Milling         | R20, R21 (M2)| 14,000                           | 42,000                      |
| Adjustment Process | R32, R33 (M3) | 10,000                           | 20,000                      |
| Spray Dryer Process | T50 (M4)  | 1,000                            | 1,000                       |
| Packing Process | R50 (M5)     | 40,000                           | 40,000                      |

The following is the processing time data of each product obtained from the production department. Each product has a different processing time which is influenced by product quality and parameters.

Table 4. Processing time for each product (hours).

|       | M1  | M2  | M3  | M4  | M5  |
|-------|-----|-----|-----|-----|-----|
| YROH (J1) | 18  | 50  | 56  | 1   | 9   |
| YHAL (J2) | 21  | 61  | 42  | 1   | 10  |
| YHAL (J3) | 19  | 46  | 63  | 1   | 13  |
| YHAL (J4) | 23  | 44  | 47  | 1   | 15  |
| YROH (J5) | 15  | 55  | 43  | 1   | 10  |
| YHAL (J6) | 19  | 58  | 39  | 1   | 10  |
| YFER (J7) | 31  | 57  | 53  | 1   | 15  |
| YROH (J8) | 17  | 31  | 54  | 1   | 9   |
| YROH (J9) | 16  | 32  | 36  | 1   | 8   |
| YROH (J10) | 19  | 37  | 40  | 1   | 11  |

Following is an example of calculating the total processing time required in M2 on J1:

Time in M2 on J1 = \( \frac{\text{Cycle time} \times \text{number of units}}{\text{production capacity}} \) = \( \frac{50 \text{ hours} \times 15,500 \text{ kg}}{14,000 \text{ kg}} \) = 55.35 hours

Machine Station Time = \( \frac{\text{Time required in M2 on J1}}{\text{Machine Amount}} \) = \( \frac{55.35}{3} \) = 18.45 hours

Table 5. The total processing time required based on each order to each machine station (hours).

| M1  | M2  | M3  | M4  | M5  | M1  | M2  | M3  | M4  | M5  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| J1  | 23.25 | 18.45 | 43.40 | 15.50 | 3.49 | J6  | 39.58 | 34.52 | 48.75 | 25.00 | 6.25 |
| J2  | 29.75 | 24.69 | 35.70 | 17.00 | 4.25 | J7  | 77.50 | 40.71 | 79.50 | 30.00 | 11.25 |
| J3  | 38.00 | 26.29 | 75.60 | 24.00 | 7.80 | J8  | 17.00 | 8.86  | 32.40 | 12.00 | 2.70 |
| J4  | 16.29 | 8.90  | 19.98 | 8.50  | 3.19 | J9  | 37.33 | 21.33 | 50.40 | 28.00 | 5.60 |
| J5  | 13.13 | 13.75 | 22.58 | 10.50 | 2.63 | J10 | 77.58 | 43.17 | 98.00 | 49.00 | 13.48 |
3.2. First Come First Served (FCFS)

Based on the FCFS method, the production order was J1-J2-J3-J4-J5-J6-J7-J8-J9-J10 with a makespan of 610.36 hours or 25 working days, can be seen in table 6.

Table 6. Makespan calculations with the FCFS method.

|     | M1       | M2       | M3       | M4       | M5       |
|-----|----------|----------|----------|----------|----------|
| J1  | 00.00/23.25 | 23.25/41.70 | 41.70/85.10 | 85.10/100.60 | 100.60/104.09 |
| J2  | 23.25/53.00 | 53.00/77.69 | 85.10/120.80 | 120.80/137.80 | 137.80/142.05 |
| J3  | 53.00/91.00 | 91.00/117.29 | 120.80/196.40 | 196.40/220.40 | 220.40/228.30 |
| J4  | 91.00/107.29 | 117.29/126.19 | 196.40/216.38 | 220.40/228.90 | 228.90/232.09 |
| J5  | 107.29/120.42 | 126.19/139.94 | 216.38/238.83 | 238.83/249.33 | 249.33/259.60 |
| J6  | 120.42/160.00 | 160.00/194.52 | 238.83/287.58 | 287.58/312.58 | 312.58/318.83 |
| J7  | 160.00/237.50 | 237.50/278.21 | 287.58/367.08 | 367.08/397.08 | 397.08/408.33 |
| J8  | 237.50/254.50 | 278.21/287.07 | 367.08/399.48 | 399.48/411.48 | 411.48/414.18 |
| J9  | 254.50/291.83 | 291.83/313.16 | 399.48/449.88 | 449.88/477.88 | 477.88/483.48 |
| J10 | 291.83/369.41 | 369.41/412.58 | 449.88/547.88 | 547.88/596.88 | 596.88/610.36 |

Note: a / b = start time / end time

Production time from start to finish for each product using the FCFS scheduling method can be seen in figure 1.

Figure 1. Job scheduling for May 2019 with the FCFS method.

3.3. Heuristic Pour

Based on calculations using the Heuristic Pour scheduling method, the optimum of job scheduling was J4-J8-J5-J1-J2-J9-J3-J10-J7-J6 with $F_{\text{max}}$ or makespan of 562.4 hours or 23 days. The makespan calculation is presented in Table 7. Production time from start to finish for each product using the Heuristic Pour scheduling method can be seen in Figure 2.
Table 7. Makespan calculation using the Heuristic Pour method.

|   | M1     | M2     | M3     | M4     | M5     |
|---|--------|--------|--------|--------|--------|
| J4| 00.00/16.29 | 16.29/25.19 | 25.19/45.17 | 45.17/53.67 | 53.67/56.86 |
| J8| 16.29/33.29 | 33.29/42.15 | 45.17/77.57 | 77.57/89.57 | 89.57/92.27 |
| J5| 33.29/46.42 | 46.42/60.17 | 77.57/100.02 | 100.02/110.52 | 110.52/113.15 |
| J1| 46.42/69.67 | 69.67/88.12 | 100.02/143.42 | 143.42/158.92 | 158.92/162.41 |
| J2| 69.67/99.42 | 99.42/124.11 | 143.20/178.90 | 178.90/195.90 | 195.90/200.15 |
| J9| 99.42/136.75 | 136.75/158.08 | 178.90/229.30 | 229.30/257.30 | 257.30/262.90 |
| J3| 136.75/174.75 | 174.75/201.04 | 229.30/304.90 | 304.90/328.90 | 328.90/336.70 |
| J10| 174.75/252.33 | 252.33/295.50 | 304.90/402.90 | 402.90/451.90 | 451.90/465.38 |
| J7| 252.33/329.83 | 329.83/370.54 | 402.90/482.40 | 482.40/512.40 | 512.40/523.64 |
| J6| 329.83/369.41 | 370.54/405.06 | 482.40/531.15 | 531.15/556.15 | 556.15/562.40 |

Note: a / b = start time / end time

Figure 2. Job scheduling for May 2019 with the Heuristic Pour method.

3.4. Campbell Dudek Smith (CDS)
The first step in compiling the CDS algorithm was to determine the number of iterations or working stages.

K (number of iterations) = number of work centre - 1 = 5 - 1 = 4

Thus the process of scheduling using the CDS method was done by 4 iterations. Find the minimum \( t_1 \) value which is the processing time on the first and second machines, where \( t_{1,1} = t_{1} \) and \( t_{1,2} = t_{2} \). According to Johnson's Rules, if the minimum time is obtained on the first machine \( t_{1} \), place the work at the beginning of the scheduling sequence and if the minimum time is obtained on the second machine \( t_{2} \), the job is placed at the end of the scheduling series. Based on the calculation using the CDS method, the sequence of jobs with the smallest makespan was 638.62 hours or 27 days with the priority sequence of jobs that was J10-J7-J3-J6-J9-J2-J1-J8-J5-J4 obtained from the 4th iteration (K4). The calculation of the makespan can be seen in Table 8. The completion time of the production process can also be seen on the Gantt Chart in Figure 3.
Table 8. Makespan calculation using the CDS method.

|     | M1          | M2          | M3          | M4          | M5          |
|-----|-------------|-------------|-------------|-------------|-------------|
| J10 | 00.00/77.58 | 77.58/120.75| 120.75/218.75| 218.75/267.75| 267.75/281.23|
| J7  | 77.58/155.08| 155.08/196.79| 218.75/298.25| 298.25/328.25| 328.25/339.50|
| J3  | 155.08/193.08| 196.79/223.08| 298.25/373.85| 373.85/397.85| 397.85/405.65|
| J6  | 193.08/232.66| 232.66/267.18| 373.85/422.60| 422.60/447.60| 447.60/453.85|
| J9  | 232.66/269.99| 269.99/291.32| 422.60/473.00| 473.00/501.00| 501.00/506.60|
| J2  | 269.99/299.74| 299.74/324.43| 473.00/508.70| 508.70/525.70| 525.70/529.95|
| J1  | 299.74/322.99| 324.43/342.88| 508.70/552.10| 552.10/567.60| 567.60/571.09|
| J8  | 322.99/339.99| 342.88/351.74| 552.10/584.50| 584.50/596.50| 596.50/599.20|
| J5  | 339.99/353.12| 353.12/366.87| 584.50/606.95| 606.95/617.45| 617.45/620.08|
| J4  | 353.12/369.41| 369.41/378.31| 606.95/626.93| 626.93/635.43| 635.43/638.62|

Figure 3. Job scheduling for May 2019 with the CDS method.

From the three scheduling methods, the smallest makespan value was found in the Heuristic Pour method. By using equation 3, it could be calculated the value of performance parameters (EI) that showed that the Heuristic Pour method was better than the scheduling method used by the company, namely FCFS.

\[
EI_{\text{Heuristic Pour}} = \frac{610.36}{562.4} = 1.085
\]

EI Heuristic Pour value > 1 which means that the performance of the Heuristic Pour scheduling method was better than the FCFS scheduling method. So the best production scheduling method for PT.X was the Heuristic Pour method with a makespan 562.4 hours (23 days) and the company could save time by 47.96 hours or 7.86% compared to the FCFS method.
4. Conclusion
The best production scheduling method for PT. XYZ was Heuristic Pour with total makespan of 562.4 hours (23 days) with the order of processing, namely Teratop Black HL-NF-01 (J4) - Orange GLN (J8) - Blue WW-2GS Successful (J5) - Terasiop Brown 2RFL (J1) - Teratop Black HL-BL (J2) - Terrain Orange HLNF (J9) - Teratop Black LF-01 (J3) - Terasil Red W-4BS (J10) - Novasol Blue RSMD (J7) - Teratop Blue HL-B (J6). By using the Heuristic Pour scheduling method the company could save time by 47.96 hours or 7.86%.

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