Heuristic methods for job shop scheduling: Active schedule generation algorithm, non-delay schedule generation algorithm and heuristic schedule generation algorithm

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Abstract. PT. Multi Citra Busana is one of the knitting material convection companies that has a good local scale marketing area where production scheduling is usually done based on the order of arrival of orders or first come first serve (FCFS). As a result, there are still some schedules that are not precise, causing a large make-span. In observations made on 5 products, the company requires a total production time (make-span) of 11 hours 54 minutes in completing production activities. In this research, scheduling evaluation is conducted to minimize make-span using the Active Schedule Generation algorithm, Non-delay Schedule Generation and Heuristic Schedule Generation algorithm. The approach used is to use a quantitative-comparative approach, namely research that compiles the calculation process to make comparisons between the results of the actual process with these methods. Through the Active Schedule Generation algorithm method, the value of make-span is 6 hours 26 minutes. Through the Non-delay Schedule Generation algorithm method, the value of make-span is 7 hours 1 minute. The Heuristic Schedule Generation algorithm method produces the smallest make-span value with a value of 6 hours 1 minute. Based on the comparison of the make-span values of the three methods used, it was concluded that the Heuristic Schedule Generation algorithm produced the smallest make-span valued at 20184.27 seconds or 6 hours 3 minutes shorter than the method applied by the company. Therefore, the Heuristic Schedule Generation algorithm method was chosen as the best method and can be applied in the company to minimize the make-span.

Keywords: job shop scheduling, non-delay schedule generation, heuristic schedule generation, active schedule generation, make-span.

1. Introduction
The effectiveness and efficiency of energy is important in the production mechanism [1]. Scheduling can be defined as an effort to organize activities or work with the aim of achieving efficient use of facilities, time, and costs [2,3]. In the production process at PT. Multi Citra Clothing only serves orders (make by order) and involves many machines in the process. In fulfilling the customer’s order, there are still machines that are unemployed while working on another job. The idle time of the machine that could have been used to do the jobs simultaneously was in vain so that there was often a delay in the completion of the job (make-span) time or exceeded the
maximum limit [4]. Make-span, which is the time required to complete all jobs in the shop, which consists of setup time between jobs and processing time per job [5]. Delay in fulfilling demand like this results in higher production costs because it takes longer to produce the product, the production schedule that should be able to run according to the plan finally changes and the loss is that consumer confidence in the company will decrease because it cannot fulfil orders in accordance with the time that has been set. Therefore, it is necessary to schedule each machine to minimize the amount and time of the delay. The reason why these methods were chosen is because this algorithm produces a fairly good scheduling sequence and is close to the optimal solution [6,7].

2. Method
Before the data is processed, the data that has been obtained is tested for the adequacy of the data first. To calculate the data adequacy test, use the equation 1 [8].

\[ N' = \frac{\text{Range}}{x} \]  

The value of \( N' \) is the amount of data that must be available and can be seen in the data sufficiency table and the condition used to determine the adequacy of the data is if \( N' < N \), then the data obtained is sufficient. But if \( N' > N \) data is not enough it is lacking and needs to be added to the data [8]. The data adequacy test formula is presented in equation 2 [8].

\[ N' = \left( \frac{k}{s} \right) \sqrt{\frac{N \sum x^2 - (\sum x)^2}{\sum x}} \]  

Where:
- \( k \) = Confidence level (99% = 3.95% = 2)
- \( s \) = Degree of accuracy
- \( N \) = Number of observational data
- \( N' \) = Amount of theoretical data
- \( \bar{x} \) = observational data

Meanwhile, if the data obtained is not sufficient, data retrieval will be carried out. Activities like this continue to be carried out until the data are sufficient and appropriate for further processing. After the data obtained is considered sufficient then a uniformity of data is tested to separate data that have different characteristics due to various influences and to ascertain whether the data collected is from the same system. The formulas used in testing data uniformity are following equation 3 to 5 [8].

\[ UCL = \bar{x} + k\sigma \]  
\[ LCL = \bar{x} - k\sigma \]  
\[ \sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{N - 1}} \]  

Where:
- \( UCL \) = upper control limit
- \( LCL \) = lower control limit
- \( \bar{x} \) = average data value
- \( \sigma \) = standard deviation
- \( k \) = level of confidence
The data that has been tested is then calculated standard time or standard time. That is the actual time used by the operator to produce one unit of product type data (equation 6 and 7) [8]. Standard time can be obtained by applying the formula:

\[
\text{Standard Time} = \text{Normal Time} + (\text{Normal time} \times \% \text{ Allowence})
\]  

\[
\text{Standard Time} = \text{Normal time} \times \frac{100}{100 - 100 \% \text{ Allowence}}
\]

After the data to be processed passes the adequacy and uniformity test of the data and the default time has been obtained, the next step that must be taken is to process the data using the methods used. In measuring the average cycle time, there are measurement steps that must be taken [6]. The stages of the research carried out in accordance with Figure 1.

3. Results and Discussion
After conducting research using the above research instruments, the following data collection was obtained. The data are shown in Table 1 and 2. For all methods, the calculation of each iteration of data processing is referring to the calculation in [9] and are shown in Table 3 to Table 5.

| Table 1. Product data and production quantities |
|------------------------------------------------|
| Name of Product | Total Product (Units) | Job Code |
|-----------------|----------------------|----------|
| Sweater         | 198                  | J1       |
| T-Shirt         | 577                  | J2       |
| Jacket          | 288                  | J3       |
| Scarf           | 134                  | J4       |
| Tank Top        | 144                  | J5       |

| Table 2. Name, number and machine code data |
|--------------------------------------------|
| Name of Machine   | Total | Code |
|-------------------|-------|------|
| Cutting Machine   | 10    | M1   |
| Sewing Machine    | 11    | M2   |
| Embroidery Machine| 13    | M3   |
| Overlock Machine  | 10    | M4   |
| Knitting Machine  | 8     | M5   |
Figure 1. Flow chart of research methodology

Start

Identification of Problem

Formulation of Problem

Literature Review

Data Collection
  - Product Data (Job)
  - Processing time data
  - Routing machine data
  - Production amount data
  - Machine data

Data Processing

Data adequacy Test
  - is the Data Enough?

Data Uniformity Test
  - is the Data uniform?

Standard Time
  - Turn Around time
  - Scheduling of actual conditions
  - Active Scheduling
  - Non-Delay Scheduling

Result and discussion

Conclusions

Finish
Based on calculations using the method of active schedule generation algorithm (Table 3), the value of make-span for the entire production process is 22527.79 seconds or 375.46 minutes. After calculating using the schedule generation non-delay algorithm method, there are 23 iterations (Table 4). Then the value of make-span for the entire production process is 24885.91 seconds or 414.77 minutes.

### Table 3. Iteration of the active schedule generation algorithm method

| Stage | Machine (Second) | St | Cj | tj | Rj | r* | m* | PSt |
|-------|------------------|----|----|----|----|----|----|-----|
|       |                  |    |    |    |    |    |    |     |
| 0     | 0                | 111| 0.00| 817.91| 817.91| 817.91| 1  | 111 |
|       | 211              | 0.00| 2910.40| 2910.40|     |     |     |     |
|       | 311              | 0.00| 4920.92| 4920.92|     |     |     |     |
|       | 415              | 0.00| 3226.93| 3226.93|     |     |     |     |
|       | 511              | 0.00| 825.89 | 825.89 |     |     |     |     |
| 1     | 817.91           | 122| 817.91| 1754.71| 2572.62| 511 |
|       | 211              | 817.91| 2910.40| 3728.31|     |     |     |     |
|       | 311              | 817.91| 4920.92| 5738.84|     |     |     |     |
|       | 415              | 0.00| 3226.93| 3226.93|     |     |     |     |
|       | 511              | 817.91| 825.89 | 1643.80| 511 |
| 2     | 1643.80          | 122| 1643.80| 1754.71| 3398.51| 522 |
|       | 211              | 1643.80| 2910.40| 4554.20|     |     |     |     |
|       | 311              | 1643.80| 4920.92| 6564.72|     |     |     |     |
|       | 415              | 0.00| 3226.93| 3226.93|     |     |     |     |
|       | 522              | 1643.80| 1201.12| 2844.92| 2844.92| 522 |
| 3     | 1643.80          | 122| 1643.80| 1754.71| 3398.51| 415 |
|       | 211              | 1643.80| 2910.40| 4554.20|     |     |     |     |
|       | 311              | 1643.80| 4920.92| 6564.72|     |     |     |     |
|       | 415              | 0.00| 3226.93| 3226.93| 3226.93| 5   |
|       | 533              | 2844.92| 1052.50| 3897.42|     |     |     |     |
| 4     | 1643.80          | 122| 1643.80| 1754.71| 3398.51| 398.51| 2  | 122 |
|       | 211              | 1643.80| 2910.40| 4554.20|     |     |     |     |
|       | 311              | 1643.80| 4920.92| 6564.72|     |     |     |     |
|       | 421              | 3226.93| 214.54 | 3441.47|     |     |     |     |
|       | 533              | 2844.92| 1052.50| 3897.42|     |     |     |     |
| Stage | Machine (Second) | St | Cj   | tij  | Rj  | r*  | m*  | PST  |
|-------|------------------|----|------|------|-----|-----|-----|------|
| 0     | 0.00 0 0 0 0 0   | 111| 0    | 817.91 | 817.91 | 817.91  | 1   | 111  |
|       |                  | 211| 0    | 2910.40 | 2910.40 |
|       |                  | 311| 0    | 4920.92 | 4920.92 |
|       |                  | 415| 0    | 3226.93 | 3226.93 |
|       |                  | 511| 0    | 825.89  | 825.89  |
| 1     | 817.91 0 0 0 0   | 122| 817.91 | 1754.71 | 2572.62  | 415  |
|       |                  | 211| 817.91 | 2910.40 | 3728.31  |
|       |                  | 311| 817.91 | 4920.92 | 5738.84  |
|       |                  | 415| 0    | 3226.93 | 3226.93  | 0    | 5  |
|       |                  | 511| 817.91 | 825.89  | 1643.80  |
| 2     | 817.91 0 0 0 3226.93 | 122| 817.91 | 1754.71 | 2572.62  | 511  |
|       |                  | 211| 817.91 | 2910.40 | 3728.31  |
|       |                  | 311| 817.91 | 4920.92 | 5738.84  |
|       |                  | 421| 3226.93 | 214.54  | 3441.47  |
|       |                  | 511| 817.91 | 825.89  | 1643.80  | 817.91  | 1   |
| 3     | 1643.80 0 0 0 3226.93 | 122| 817.91 | 1754.71 | 2572.62  | 817.91  | 2   | 122 |
|       |                  | 211| 1643.80 | 2910.40 | 4554.20  |
|       |                  | 311| 1643.80 | 4920.92 | 6564.72  |
|       |                  | 421| 3226.93 | 214.54  | 3441.47  |
|       |                  | 522| 1643.80 | 1201.12 | 2844.92  |
### Table 5. Iteration of schedule generation non-delay algorithm methods

| stage | Machine (Second) | St | Cj | MWKR Priority | MWKR | PSt |
|-------|------------------|----|----|----------------|------|-----|
| 0     | 0                | 0  | 0  | 0              | 0    | 0   |
|       | 211              | 0  | 0  | 0              | 0    | 0   |
|       | 311              | 0  | 0  | 19086.32       | 19086.32 | 311 |
|       | 415              | 0  | 0  | 4140.14        |      |     |
|       | 511              | 0  | 0  | 5951.02        |      |     |
| 1     | 4920.921         | 0  | 0  | 0              | 0    | 0   |
|       | 211              | 0  | 0  | 0              | 0    | 0   |
|       | 322              | 0  | 0  | 0              | 0    | 0   |
|       | 415              | 0  | 0  | 0              | 0    | 0   |
|       | 511              | 0  | 0  | 0              | 0    | 0   |
| 2     | 7831.318         | 0  | 0  | 0              | 0    | 0   |
|       | 222              | 0  | 0  | 0              | 0    | 0   |
|       | 322              | 0  | 0  | 0              | 0    | 0   |
|       | 415              | 0  | 0  | 0              | 0    | 0   |
|       | 511              | 0  | 0  | 0              | 0    | 0   |
| 3     | 8649.232         | 0  | 0  | 0              | 0    | 0   |
|       | 222              | 0  | 0  | 0              | 0    | 0   |
|       | 322              | 0  | 0  | 0              | 0    | 0   |
|       | 415              | 0  | 0  | 0              | 0    | 0   |
|       | 511              | 0  | 0  | 0              | 0    | 0   |
| 4     | 9475.12          | 0  | 0  | 0              | 0    | 0   |
|       | 222              | 0  | 0  | 0              | 0    | 0   |
|       | 322              | 0  | 0  | 0              | 0    | 0   |
|       | 415              | 0  | 0  | 0              | 0    | 0   |

After calculating using the Heuristic Schedule Generation algorithm method, there are 23 iterations. The obtained value of *make-span* for the entire production process is 20184.27 seconds or 336.41 minutes.

### Table 6. Sorting of actual job conditions

| Machine | 111 | 211 | 311 | 421 | 511 |
|---------|-----|-----|-----|-----|-----|
| M1      | 111 | 211 | 311 | 421 | 511 |
| M2      | 122 | 152 | 222 | 322 | 342 |
| M3      | 143 | 243 | 353 | 432 | 522 |
| M4      | 254 | 334 | 364 | 542 |     |
| M5      | 135 | 211 | 311 | 421 | 511 |
From the Table 6 it can be seen the sequence of work performed by each machine as follows:

- **M1:** J1 Op1 (1,1,1), continued J2 Op1 (2,1,1), continued J3 Op1 (3,1,1), continued J4 Op2 (4,2,1) and continued by J5 Op3 (5,1,1).
- **M2:** J1 Op2 (1,2,2), continued J1 Op5 (1,5,2), continued J2 Op2 (2,2,2), continued J3 Op2 (3,2,2), continued J3 Op4 (3,4,2), continued J4 Op3 (4,3,2), continued J5 Op2 (5,2,2), and ended with J5 Op4 (5,4,2).

The results of job sorting all methods of algorithm is following Table 7. We can see the sequence of work performed by each machine as follows:

- **M1:** J1 Op1 (1,1,1), continued J5 Op1 (5,1,1), continued J2 Op1 (2,1,1), continued J4 Op2 (4,2,1), continued J3 Op1 (3,1,1)
- **M2:** J5 Op2 (5,2,2), continued J1 Op2 (1,2,2), continued J4 Op3 (4,3,2), continued J5 Op4 (5,4,2), continued J1 Op5 (1,5,2), continued J2 Op2 (2,2,2), continued J3 Op2 (3,2,2), and ended with J3 Op4 (3,4,2)

| Table 7. Job sorting method active schedule generation |
|------------------------------------------------------|
| Machine | Job Sequencing |
|---------|----------------|
| M1      | 111 511 421 211 231 311 |
| M2      | 522 122 432 542 152 222 322 342 |
| M3      | 533 143 243 353 |
| M4      | 554 254 334 364 |
| M5      | 415 135 |

| Table 8. Job Ordering Non-delay Schedule Generation Method |
|------------------------------------------------------------|
| Machine | Job sequencing |
|---------|----------------|
| M1      | 111 511 211 421 311 231 |
| M2      | 122 522 542 222 432 152 322 342 |
| M3      | 533 143 243 353 |
| M4      | 554 254 334 364 |
| M5      | 415 135 |

From Table 8 it can be seen that the sequence of work performed by each machine is as follows:

- **M1:** J1 Op1 (1,1,1), continued J5 Op1 (5,1,1), continued J2 Op1 (2,1,1), continued J4 Op2 (4,2,1), continued J3 Op1 (3,1,1) and continued with J2 Op3 (2,3,1)
- **M2:** J1 Op2 (1,2,2), followed by J5 Op2 (5,2,2), followed by J5 Op4 (5,4,2), followed by J2 Op2 (2,2,2), followed by J4 Op3 (4,3,2), followed by J1 Op5 (1,5,2), followed by J3 Op2 (3,2,2), and ended with J3 Op4 (3,4,2).

Meanwhile, Table 9 shows the sequence of work performed by each machine as follows:

- **M1:** J3 Op1 (3,1,1), followed by J2 Op1 (2,1,1), followed by J1 Op1 (1,1,1), followed by J5 Op1 (5,1,1), followed by J4 Op2 (4,2,1) and continued with J2 Op3 (2,3,1).
- **M2:** J3 Op2 (3,2,2), followed by J1 Op2 (1,2,2), followed by J5 Op2 (5,2,2), followed by J2 Op2 (2,2,2), followed by J4 Op3 (4,3,2), followed by J3 Op4 (3,4,2), followed by J5 Op4 (5,4,2), and ending with J1 Op5 (1,5,2).
Summary of the three methods compare with the actual condition is presented in Table 10.

Table 9. Job ordering heuristic schedule generation method

| Machine | Job Sequencing |
|---------|----------------|
| M1      | 311 211 111 511 421 231 |
| M2      | 322 122 522 222 432 542 152 |
| M3      | 533 243 143 353 363 |
| M4      | 334 554 254 |
| M5      | 415 135 |

Table 10. Job sequence and make-span value of each method

| No. | Scheduling                                      | Make-span |
|-----|-------------------------------------------------|-----------|
|     |                                                 | Second    | Minute   | Hours    |
| 1   | Actual Conditions                               | 41536.49  | 692.27   | 11 h 54 m|
| 2   | Active Schedule Generation Algorithm            | 22527.79  | 375.46   | 6 h 26 m |
| 3   | Non-delay Schedule Generation Algorithm         | 24885.91  | 414.77   | 7 h 31 m |
| 4   | Heuristic Schedule Generation Algorithm         | 20184.27  | 336.41   | 6 h 1 m  |

4. Conclusions
Based on the analysis and discussion carried out before, the following conclusions can be drawn. Based on the comparison of the make-span values of the three methods used, it was concluded that the heuristic schedule generation algorithm method produced the smallest makespan worth 20184.27 seconds or 6 hours 1 minute seconds shorter than the method applied by the company. Thus, the heuristic schedule generation algorithm method was chosen as the best method and can be applied in the company to minimize the make-span.

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