Comparison of Scheduling Methods for Optimization Production Processes on PT. P

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***Abstract*— This study aims to determine scheduling methods to optimize the manufacturing production process. One of which way to optimize the manufacturing process is to ensure that the production capacity is used optimally. Scheduling planning is a tool to allocate capacity and resources for the process from time to time. The author proposes the earliest due date (EDD) scheduling method to be compared with critical ratio (CR) and first come first serve (FCFS) method for optimizing the manufacturing production process on PT.P. Several tests are conducted to prove the performance of the scheduling method, with regard to scheduling parameters and their impact on the manufacturing production process. The scheduling parameters referred to are Flow Time, Makespan, Tardiness, and Late Jobs. For its effect on the manufacturing production process, the utility value of the machine capacity used will be measured while using the scheduling method. The test results obtained from the earliest due date method (EDD) succeeded in producing the value of makespan 3.41% shorter, and the mean flow time is 0.70% shorter. This method also improved the utility of the machine, on average 2.34% better than other methods without increasing the mean tardiness and the number of late jobs overall.**

Keywords—Job Shop; Manufacture; Operation; Optimization; Scheduling;

I. INTRODUCTION

Manufacturing activities [1] are production activities carried out using labor, machinery, and other equipment to produce goods—one of the manufacturing companies in Indonesia, PT. P is a business entity in the manufacturing and medical devices industry, which was founded in 2017.

In conducting production activities, PT. P uses the Job Shop [2] flow (the flow in which non-consecutive cross-product jobs) based on the number of product variations offered and the layout of the production machine applied. Although PT. P has been actively running since 2017 but the factory has not been running effectively and optimally, moreover, problems such as scheduling are commonly happened.

An enormous amount of research has been carried out regarding scheduling problems both in informatics and operations. Some solutions to problems produced by similar studies are not practical to apply and easily understand by humans.

This research proposes a method using priority rules that are easy to understand and practical to apply directly to the manufacturing industry environment. The used methods in this study are Early Due Date (EDD) method because this method is favorable in manufacture industry, First Come First Serve (FCFS) method is commonly used in services industry like banking industry and Critical Ratio (CR) method due to the simplicity of using two variables for analyzing.

Performance testing [3] of the scheduling method used in this study will be reviewed from several parameters, namely: *mean flow time* $F = \frac{1}{n_{i=1}} \sum_{i=1}^{n} F_i$ [4]., *makespan* C_{max}, *mean tardiness* $T_s = \frac{1}{n} \sum_{i=1}^{n} T_i$ [4], [5], *dan Number of Late Job* $\sum U_i$.

Aside of reviewing aspects of the scheduling parameters generated, the scheduling method to be tested is also evaluated [6] in terms of the significance of the impact on the manufacturing production process [7] of the machine utility parameter. Therefore, the manufacturing industry could rely on the proven method through this research in carrying out scheduling [8] planning [9].

II. RELATED THEORY

A. Flow Time, Makespan, Tardiness, Late Jobs

Flow time is the total time [10] needed to complete a job, while makespan is an indicator of the length of time required by the system in completing the set of work. A minimum makespan indicates the system works efficiently in resources, yet still able to increase the total flow time $\sum C_i$ of incoming work [11]. Tardiness is the number of work time [12] units that exceed the work deadline [11]. Finally, late jobs are jobs that have finished beyond the time limit specified.

B. Job Shop Scheduling Problem

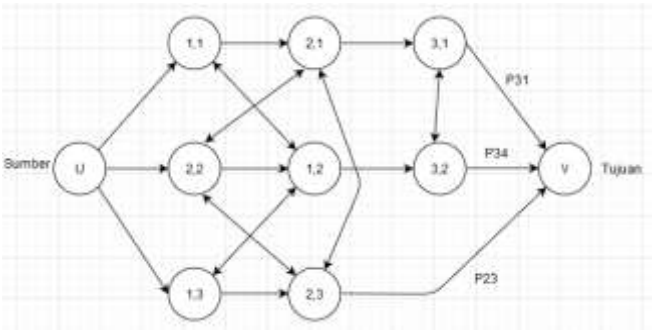

Fig 1. Graph job shop with makespan target [5]

Ref [4] tells the importance of time and cost for job shop, yet in this study is more focusing on implying it in a practical approach. The Job Shop Scheduling Problem (JSSP) is $n \times m$ where there are sets of n Jobs [13] $\{J_i\}1 \leq n$ that will be processed on the set machines m $\{M_r\}1 \leq r \leq m$. Each Jobs [13] has a production sequence (J_i) that was processed on the machine (M_r). The process of working on the machine (M_r) is called operation (O_{jr}.) Each operation O_{jr} that is processed on the machine M_r takes an exclusive process time called P_{jr}. Scheduling is a set of completion time for each operation $\{C_{jr}\}1 \leq j \leq n, 1 \leq r \leq m$

The difference between *job shop* (J_m) *scheduling problem* and *flow shop* (F_m) *scheduling problem* is that the flow of activities in each job does not have to be the same; this results in scheduling the job shop process to be shorter because it is more flexible [4]. In general, the Job Shop problem will require more complicated computing [14] than the $F_m || C_{max}$Invalid source specified. case. This can be illustrated in Figure 1. The model $J_m||C_{max}$ can be completed with SPT-LPT [5],[11] and SBH [10].

C. Priority Rules

Priority Rules [15] are methods of scheduling work based on priority. The purpose of priority rules is to minimize the completion time of all work, increase the use of available resources, and reduce the amount of late work. There are several priority rules, namely:

1. First Come First Serve (FCFS)
2. Earliest Due Date (EDD)
3. Shortest Processing Time (SPT)
4. Longest Processing Time (LPT)
5. Critical Ratio (CR)

III. PROPOSED METHOD

The methods that are tested to optimize the manufacturing production process, namely are the Earliest Due Date (EDD) method, the First Come First Serve (FCFS) method, and the Critical Ratio method.

A. Earliest Due Date

Earliest Due Date (EDD) method is a method for scheduling work based on the deadline for the work closest to scheduling. For example in Table I.There are three examples of jobs that illustrated in Table I; each job has a processing time on the machine M_1 and has a deadline. For the example cases in Table I, while using EDD method the order of jobs in the scheduling is 3 - 1 - 2.

B. First Come First Serve

First Come First Serve (FCFS) method is a method to schedule works based on the order of arrival of work that will be scheduled. In Table II there are three examples of jobs in which each job has a processing time on the machine M_1. Based on the case in Table II, therefore, the order of the works is 1-2-3.

C. Critical Ratio

Critical Ratio is a method for scheduling work based on values in Equation (1)

$$CR = time\ remaining / works\ day\ remaining \quad (1)$$

Equation (1) is a formula for calculating Critical Ratio values. The following are explanations of the value of the critical ratio:

1. If the value of CR is below than 1.0, then the work has exceeded the deadline for completion.
2. If the value of CR is equal to 1.0, then it is right on schedule
3. If the value of CR is greater than 1.0, then it indicates the job still has a lot of time.

When scheduling using the Critical Ratio method, work is scheduled based on the smallest value of CR. An example is in Table III.

TABLE. I. EXAMPLE OF EDD

Job	M1	Due
1	10	13
2	5	21
3	7	7

TABLE. II. EXAMPLE OF FCFS

Job	M1	Due
1	4	11
2	2	8
3	1	3

TABLE. III. EXAMPLES OF CR

t = 6			
Job	***M1***	***Due***	***CR***

1	7	8	0.29
2	3	13	2.3
3	12	19	1.08

TABLE. IV. EXAMPLES OF CR II

t =9			
Job	***M1***	***Due***	***CR***
1	7	8	-0.14
2	3	13	1.3
3	12	19	0.83

Table III shows three examples of works; each job has different processing time on the machine M_1 and has a different deadline; therefore, the order of jobs in scheduling is 1-3-2. Where in Table IV, there are three jobs which each job has a process timing and a deadline on the machine M_1. Based on Table IV; therefore, the order of the jobs for the 9th time on scheduling is 3-2.

The value of CR from each job on scheduling process changes over time; this makes the Critical Ratio method more dynamic.

IV. RESULT AND DISCUSSION

This study aims to determine which method able to optimize the manufacture of production processes. Retrieval of test data on the Earliest Due Date (EDD), First Come First Serve (FCFS), and Critical Ratio (CR) methods were carried out by surveying directly to PT.P. The test data is then processed; therefore, the confidentiality of PT. P is maintained. Table V shows the processes in PT. P where W1, W2 and W3 mean design process, molding process and process of finishing.

The data in Table V can be described as $n \times m$ where there are sets on n jobs $\{J_i\}1 \leq n$ that are processed on the set of m Machine $\{M_r\}1 \leq r \leq m$. Each *Jobs* has a production order that will be processed on the machine. The process of working J_i on machine M_r is called operation O_{jr}. Each operation of O_{jr} that is processed on machine M_r takes an exclusive time process called P_{jr}.

TABLE. V. TEST DATA IN PT.P

Job	W 1	W 2	W 3	Due
1	7	7	3	60
2		6	1	9
3			2	10
4			1	10
5	5	5	2	76
6		6	2	28
7			3	12
8	5	5	1	86
9			2	12
10	8	6	2	81
11			3	34
12		6	2	52
13	6	8	2	65
14			3	46
15			3	51
16	8	7	2	71
17		7	3	21
18	7	7	3	62
19		7	3	23
20		7	3	42

TABLE. VI TEST RESULTS ON EACH METHOD

Method	Mean Flow Time	Mean Tardiness	Makespan	Late Jobs
FCFS	34.5	3.4	87	6
EDD	35.35	0	85	0
CR	35.6	0	85	0

Table VI shows the results of testing the performance of the tested methods. For FCFS, the mean flow time is 34.5, the mean tardiness is 3.4, makespan is 87, and Late Jobs is 6.

This method has the lowest average flow time, yet has the highest tardiness value and makespan value. While for EDD produces a mean flow time of 3.45, makespan of 85, and does not have late work as well as tardiness value.

For the CR method, the mean flow time is 35.6 and makespan is 85. This method has the highest flow time without having late works and means tardiness.

Table VII consists the result of the machine's utility test for each method, from these results it can be seen that the Earliest Due Date (EDD) method has the same results as the Critical Ratio method. Utility tests [16] are carried out using the formula [17] in Equation (2).

$$Utilty = \frac{sum\ of\ processing\ time\ on\ M_i}{C_{max}} \times 100\% (2)$$

where:

$sum\ of\ processing\ time\ on\ M_i$: is the total processing time on each W1, W2 and W3.

C_{max} : is makespan.

The EDD method and the CR method appear to have similarities to the test results in this case study. However, the results of the set of sets $_1$ for scheduling of the two methods are different, resulting in different mean flow times.

TABLE. VII. MACHINE'S UTILITY TABLE FOR EACH METHOD.

Method	W1	W2	W3
FCFS	52.87%	96.55 %	52.87%
EDD	54.11%	98.82 %	54.11%
CR	54.11%	98.82 %	54.11%

TABLE VIII. EDD SCHEDULING RESULTS FOR W1

Job	Process Time	Flow Time

1	7	7
18	7	14
13	6	20
16	8	28
5	5	33
10	8	41
8	5	46
total flow time		189

Table VIII contains the flow time and job scheduling sequence of the EDD method. In W1 has a total flow time value of 189, Furthermore; for scheduling work on W1 with the CR method is in Table VIII.

A flow time and scheduling order is shown in Table IX, where the CR method on W1 has a total value of 192. From the two results of the scheduling method on different W1 are the order of jobs 10 and job 5.

The scheduling data using the Critical Ratio method for t =28 is shown in Table X, where the scheduling order from the Critical Ratio method is 10 - 5. Moreover, from Table IX for scheduling, the EDD method produces a sequence of 5-10 in W1. The same thing happened in schedule on W3.

TABLE. IX. CR SCHEDULING RESULTS FOR W1

Job	**Process Time**	**Flow Time**
1	7	7
18	7	14
13	6	20
16	8	28
10	8	36
5	5	41
8	5	46
total flow time		192

TABLE. X. CR VALUE FOR T = 28

t = 28					
Job	***w1***	***w2***	***w3***	***due***	***CR***
10	8	6	2	81	3.31
5	5	5	2	76	4

TABLE. VIII. THE RESULT OF SCHEDULING ON W3 USING CR

Job	**w3**	**Flow Time**
7	3	3
3	2	5
9	2	7
2	1	8
4	1	9
11	3	12
17	3	16
14	3	19
19	3	23
15	3	26
6	2	28
20	3	36
12	2	41
1	3	49
18	3	56
13	2	63
16	2	70
5	2	75
10	2	81
8	1	85
total flow time		712

Table XI shows the result of scheduling in W3 using the CR method, where the total flow time of scheduling on W3 is 712. Furthermore, the results of scheduling on W3 using the EDD described by Table XII.

TABLE. XII. RESULTS OF SCHEDULING ON W3 USING EDD

Job	**w3**	**Flow Time**
3	2	2
4	1	3
7	3	6
2	1	7
9	2	9
11	3	12
17	3	16
14	3	19
19	3	23
15	3	26
6	2	28
20	3	36
12	2	41
1	3	49
18	3	56
13	2	63

16	2	70
5	2	75
10	2	81
8	1	85
total flow time		707

Table XII shows the results on W3 using the EDD method; the total flow time of scheduling on W3 is 707. The results of scheduling in both tables X and XI show that the initial scheduling sequence in W3 using the EDD method is 3-4-7-2-9. As for the initial scheduling sequence in W3 using the CR method it produces 7-3-9-2-4-... Therefore, the difference in total flow time produced makes the EDD method superior in mean flow time.

TABLE. XIII. FCFS METHOD SCHEDULING RESULTS.

Job	**W1**	**W2**	**W3**	**Due**	**Flow Time**	**Tardiness**
1	7	7	3	60	49	0
2		6	1	9	18	9
3			2	10	2	0
4			1	10	3	0
5	5	5	2	76	53	0
6		6	2	28	20	0
7			3	12	6	0
8	5	5	1	86	57	0
9			2	12	8	0
10	8	6	2	81	64	0
11			3	34	11	0
12		6	2	52	22	0
13	6	8	2	65	72	7
14			3	46	14	0
15			3	51	17	0
16	8	7	2	71	79	8
17		7	3	21	28	7
18	7	7	3	62	87	25
19		7	3	23	35	12
20		7	3	42	42	0
Total					687	68

Table XIII contains the results of scheduling using the First Come First Serve (FCFS) method. On the results of scheduling using the FCFS method, there are 6 jobs that exceed the deadline for the workmanship with a total Tardiness of 68. However, the scheduling of the FCFS method produces a total flow time of 687. Therefore, for the mean flow time parameter scheduling the FCFS method is the most optimal among other methods with a value of 34.5.

V. CONCLUSION

The conclusion that can be drawn from this study is the earliest due date (EDD) scheduling method produces better performance scheduling for the manufacturing production process than the first come first serve (FCFS) scheduling and the critical ratio (CR) scheduling method. Regarding the scheduling parameters of the production process, the EDD method produces a makespan value of 3.41% shorter than the FCFS scheduling method. The EDD scheduling method does not produce Tardiness and does not produce work that is past the deadline. For the mean flow time parameter, the EDD scheduling method yields a value of 0.70% shorter than the CR scheduling method. In terms of the production process the EDD scheduling method, on average, increases the utility of the machine in the production process by 2.34% than the FCFS scheduling method. The results of the study are only for job shop cases.

VI. ACKNOWLEDGMENT

The authors would like to sincerely thank Institut Teknologi Sepuluh Nopember, the Directorate of Higher Education, Indonesian Ministry of Education and Culture, and LPDP through RISPRO Invitation Program for funding the research.

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