Scheduling N Jobs on Identical Parallel Machines in PT XYZ to Reduce Total Tardiness Using Earliest Due Date Rules and Job Splitting Property

1st Tengku Khalida Zia Giovanny
School of Industrial Engineering
Telkom University
Bandung, Indonesia
tengkuzia@student.telkomuniversity.ac.id

2nd Dida Diah Damayanti
School of Industrial Engineering
Telkom University
Bandung, Indonesia
didadiah@telkomuniversity.ac.id

3rd Ayudita Oktafiani
School of Industrial Engineering
Telkom University
Bandung, Indonesia
ayuditaoktafiani@telkomuniversity.ac.id

***Abstract*—This research focus on reducing total tardiness on single-stage identical parallel machine in PT XYZ. The method used are EDD rules where the job is sorted based on earliest due date and job splitting property where the job is split between the machine with maximum tardiness and the machine with minimum tardiness. The proposed method managed to yield successful result by decreasing the total tardiness up to 33%.**

***Keywords*— identical parallel machine scheduling, EDD, job splitting property**

I. PREFACE

PT XYZ is a plastic manufacturing company that operates in Bandung. Registered as a company in 1993, the company had been a supplier of high quality product, in-time delivery, and high customer satisfaction. Its quality is guaranteed through certification from ISO 9001: 2015 that has been given in 2020. The company's vision is to provide molds & plastic products, dies, jigs, & fixtures, precision parts, and general mechanics of the highest quality and secure product for the satisfaction of the customer.

The company does not do forecasting. The production system that was implanted by the company is make-to-order (MTO). The order is received by the company in advance, where the customer specifies the amount of product they require and when the product should be delivered. The company had four injection molding machines to support the production process. These four machines are the same type with the same capabilities and capacity. Therefore, all jobs that were received by the company can be processed by those four machines.

The injection molding machines can shape plastic according to its mold. Before the production, the mold is mounted on the machine. The operator will then operate the machine where it will mold the plastic into the desired shape. The result of the molding is the final product that will be packed and delivered to the customer.

Based on the above explanation, the system in the company is single-stage production in an identical parallel machine system. This kind of problem falls into NP-hard problems with m machine and n jobs [1]. The company uses the First Come First Serve (FCFS) scheduling system.

In May 2021, the company did not manage to meet all the customer's due dates. Out of 145 jobs in that month, the number of tardy jobs is 26 with total tardiness is 64.

TABLE 1
(PT XYZ Scheduling's Performance)

Machine	Number of Jobs	Total Tardiness (Days)	Tardy Jobs
1	40	6	3
2	37	5	4
3	36	32	11
4	32	21	8
Total	**145**	**64**	**26**

Tardiness is an indicator of how well the company could meet the demand's due dates. The tardiness itself is influenced by the company's capacity and the company's scheduling system. Sufficient capacity is required to meet the customer's demand in time [2]. While tardiness is one of scheduling's performance measures.

TABLE 2
(Possible Root Cause)

Symptoms	Possible Root Cause
Tardiness in fulfilling demand	Under capacity
	Inadequate scheduling system

Both capacity and scheduling are part of an integrated system in production planning and control, where it manages human, materials, information, and machines. The problem that will be the focus of the research is a complex problem. This is evidenced by the existence of several alternative solutions to the problems in the object of research.

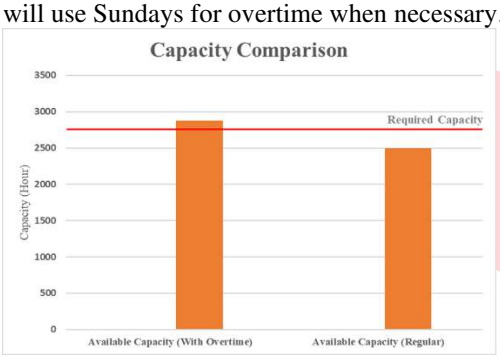
TABLE 3
(Alternative Solution)

Root Cause	Solution
Under capacity	Increase the company's capacity
Inadequate Scheduling	Design a better scheduling system for the company

To determine which alternative solution that will be selected, an analysis is made on the root causes and their alternative solution.

A. Under capacity

If a company does not have the required capacity, it is impossible to meet the customer's demand in time. Based on the data provided by the company, a rough capacity calculation was made and compared with the required capacity for May 2021. The workdays for machine operators are from Monday to Saturday, where every day there are three shifts available, each shift lasting eight hours. If there is an influx in demand, the company will use Sundays for overtime when necessary.



Based on the figure, the company had enough capacity to fulfill the required demands by using available capacity with overtime. Capacity increase speeds up the production process to meet the customer's demand faster. Increasing capacity could be done by a few alternatives, such as adding more machines and workers. However, capacity increase will require substantial investment by the company.

B. Inadequate Scheduling

Scheduling performance can be measured through certain parameters such as tardiness and makespan. Since the capacity is sufficient, then the tardiness in the company reflects the existing scheduling performance. In scheduling, there are several methods that can be used to improve the scheduling. Each method has both advantages and disadvantages. While choosing the method for scheduling, it is important to consider the constraint and the objective at hand. The problem addressed in the research is how to reduce total tardiness.

As mentioned in the background, the system in the company is identical parallel machines systems, where the jobs to be processed is over a hundred jobs, and identical parallel machine problem are categorized as NP-hard problems. The best approach to solve the tardiness problem is from scheduling, particularly scheduling using a heuristic method where the solution provided is simpler to calculate and can be implemented without additional cost required

Based on the background provided, the following is the objective of the research The objective of the research is to design an algorithm that could reduce total tardiness to be applied in PT XYZ

II. LITERATURE STUDY

A. Production Planning

Production planning is an activity that involves planning what products to be produced, the number of products that will be produced, and when the product will be produced. Production planning activities include scheduling [3].

B. Scheduling

Scheduling is defined as a type of decision-making that deals with allocating limited resources to activities [4]. Parallel machines in scheduling are where several identical machines are available, and the jobs can be processed on any of them [5].

C. EDD Rules

Earliest Due Date (EDD) is a method where the job is sequenced from the job that has the earliest due date. This method is effective to minimize tardiness in parallel machines [6]. If all jobs have the same due dates, then tardiness will be minimized by SPT sequencing [7].

D. Job Splitting

Job splitting is a property of scheduling. The idea is to split a job into sub-jobs that will be processed on different machines, the sub-jobs can be processed simultaneously on different parallel machines [8]. The concept of job splitting in general is to reduce the production lead time that can minimize the overall job tardiness [9]. In this research, it was assumed that all the jobs are available at a time zero and all machines are available at ready time.

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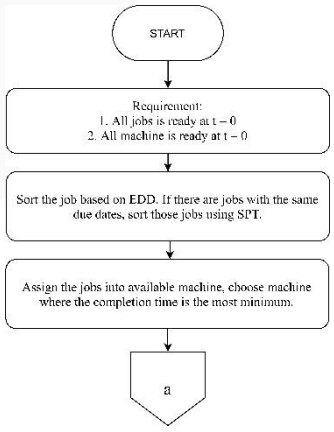
III. METODE

The method used in this research is illustrated on figure 1.



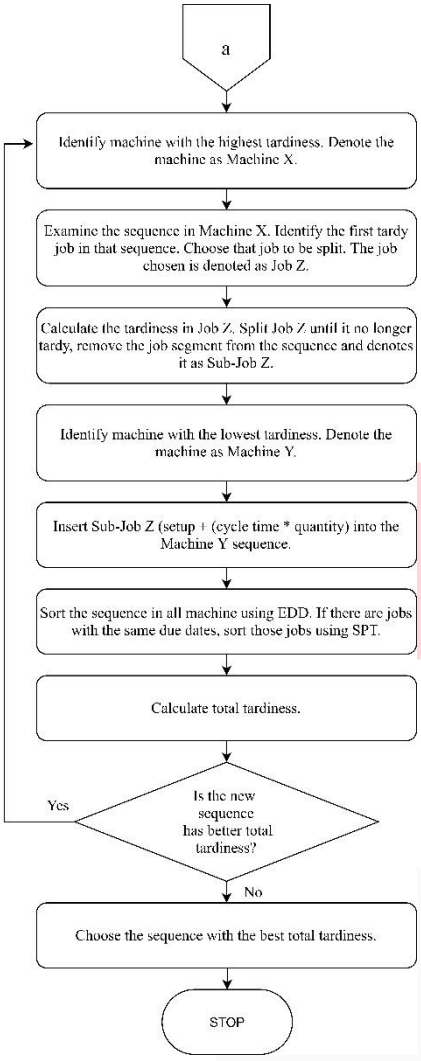


FIGURE 1
(Design Methodology)

A. EDD Rules

The following are the steps of EDD rules used in this research.

Step 1. Set the jobs by their due dates in ascending order. If the job has the same due dates, then sort based on its processing time from shortest to longest. The jobs that have been sorted is put into unscheduled job set.

Step 2. Select job *i* from unscheduled job set and select machine j that is the machine with lowest scheduled total times. Assign job *i* in machine j and delete it from unscheduled job set.

Step 3. If there is no job left in the unscheduled job set, go to

Step 4; otherwise go to Step 2. Step 4. All jobs are scheduled

B. Job Splitting

This research uses a heuristic algorithm for parallel machine scheduling problem with setup time and job splitting property. When a job is split into sub-jobs, the quantity is split, and an additional setup time will be added to the processing time. EDD schedule that was obtained previously is used as the initial solution for the job splitting. The following are the steps to schedule the jobs using proposed job splitting algorithm.

Step 1. From the initial solution, identify the machine with the maximum tardiness. This machine is denoted as Machine X.

Step 2. From the sequence in the machine X, identify the first tardy job in the sequence and choose that job to be split. The job chosen is denoted as Job X.

Step 3. Split Job X in such a way that until it no longer tardy (tardiness value = 0). Remove the job segment from the sequence, this segment is denoted as Sub-Job X.

Step 4. Identify the machine with minimum tardiness. This machine is denoted as Machine Y.

Step 5. Insert Sub Job X into Machine Y. Sort the sequence in all machines using EDD rules.

Step 6. Calculate total tardiness. Repeat step 1-4 until the total tardiness no longer decreasing

IV. RESULT AND DISCUSSION

The scheduling performance is calculated. Table IV.5.1.1 shows the detail of EDD scheduling's performance in terms of tardiness.

EDD Scheduling's Tardiness and Completion Time

Machine	Total Job	Tardiness (Days)	Completion Time (Sec)
M1	49	14	1.766.400
M2	35	10	1.863.000
M3	32	9	1.897.200
M4	29	12	1.802.400
Total	**145**	**45**	**7.329.000**

The scheduling performance is calculated. The table shows the detail of EDD scheduling's performance in terms of tardiness.

Job Splitting's Scheduling Performance

Machine	Total Job	Tardiness (Days)	Completion Time (Sec)
M1	49	14	1.766.400
M2	35	17	1.983.900
M3	33	9	1.897.200
M4	29	3	1.685.100
Total	**146**	**43**	**7.332.600**

Based on the table, EDD managed to bring down the total tardiness from 64 days to 45 days. The job splitting reduces the tardiness further, from 45 days to 43 days. That means there are 33% decrease in total tardiness from the original scheduling. Compared to the existing condition, the number of tardy jobs also went down from 26 jobs to 24 jobs in job splitting's schedule. The reduced total tardiness and tardy jobs means that the proposed scheduling had managed to prioritize job with early due date first and then

spread the job between machine with the most tardiness and the least tardiness to reduce total tardiness.

In terms of makespan, scheduling using job splitting is has a potential to increase makespan since the overall processing time of the jobs are increased by setup time. The makespan went down from 2.032.200 seconds in existing condition to 1.983.900 seconds in job splitting's schedule, but the smallest makespan belong to EDD scheduling with the value of 1.897.200 seconds.

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