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GENERATE AND TEST ALGORITHM DEVELOPMENT FOR JOB SCHEDULING IN PARALLEL MACHINES WHICH CONSIDERING SETUP TIME FOR MINIMIZING TARDINESS AND MINIMIZING MAKESPAN FOR ALTERNATIVE SEQUENCES THAT HAVE SAME TARDINESS

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ABSTRACT

Search for solutions to generate and test algorithm guarantees the optimal value of the desired results. However, the main constraint is the limitation of element number. Number of input elements may lead to a lot of combinations of alternative solutions, the number may increase exponentially. The application of this algorithm in job scheduling would not be suitable for cases that have a large number of jobs. In this study raised the case of PT Agronesia Inkaba for job scheduling in general press division. Generate and test algorithm can accommodate more than one objective. In this case the main assessment criteria scheduling is total tardiness. If it has the same total tardiness then will compare the makespan. It is quite difficult to be represented using mathematical formulas or using metaheuristic methods. One more thing that increases complexity is the consideration of setup time when a machine will make a new product or a different product than the one before. The results obtained from the use of generate and test algorithm is optimal and much better than existing heuristic methods. Comparison method used is the method of EDD (Earliest Due Date), Wilkerson Irwin algorithm, Slack methods, and methods of LPT (Longest Processing Time).

Keywords: *job scheduling, tardiness, makespan, Generate and Test, parallel machine*

1. INTRODUCTION

Concept of parallel operations widely used in the manufacturing environment. On a job shop layout, the machines are grouped according to function and placed in the same department. When a job arrives in the department and will be processed, then the scheduling must be determined and assign on existing machines. There are two performance measures that are widely used, namely makespan and mean tardiness (Elsayed, 1994).

Optimal method with analytical model is very difficult to obtain because so many variations. These make the difficulties to construct mathematical formulas. Another thing that is growing is the heuristic methods, which are relatively simple mathematical model but does not assure the optimal outcome. These methods include: modification shortest processing time (SPT) to minimize the mean flow time on m parallel processors (Bedworth, 1982); combination longest processing time (LPT) with SPT to reduce the makespan (Bedworth, 1982); Distributed Earliest Due Date (EDD) to reduce the maximum tardiness (Bedworth, 1982); Distributed Slack method for reducing tardiness (Bedworth, 1982); Distributed Wilkerson Irwin method for reducing the average tardiness (Bedworth, 1982); Modified EDD to reduce the number of jobs that are tardy (Bedworth, 1982).

Metaheuristic methods often used to solve scheduling problems. The results may or may not be optimal but is able to find a good solution in the very broad state space. If there were n number of job and will be assigned to m parallel machines then the number of combinations is n! (Chase, 2004). If n > 15 then the number of combinations are 15!, This leads to inefficient search time if we want to show the whole combination. The metaheuristic method would be most suitable for this problem. However, if the number of jobs is under 15 then generating all combinations are possible with the help of modern computer technologies. One method that generates all the combinations is Generate and Test method.

Generate and Test method is a method of exhaustive search or enumeration so as to find an optimal solution. The problem that arises is the number of alternatives that must be tested and it is the time-consuming search process. Number of jobs that are not too large can still use this method especially supported by the latest computer device capabilities so that the search process will be much faster.

Case study to test this method is the problem at manufacturing field in PT Agronesia Inkaba. The company manufactures products made from raw rubber. Production scheduling methods that companies use today just look at the job order arrival time, the job that come earlier will be produced first. The scheduling method applied by the company at this time, indicates the company has not considered the optimal job sequence to reduce or minimize tardiness in order to meet the customer orders. The challenge is there are jobs that are experiencing tardiness due to the completion time of jobs exceed the maximum limit (due date), causing the company is exposed to penalty. The penalty is calculated based on the total tardiness. To reduce the total tardiness in the fulfillment of the jobs, the company is required to be able to design job scheduling system that effective and efficient, so that the entire orders can be met in time. The Generate and Test method are proposed scheduling method that should be used by the company in order to minimize total tardiness and makespan.

2. THEORETICAL BACKGROUND

Scheduling is the allocation of resources over time to perform a collection of tasks. Each production plans will produce a detailed schedule of the total production during the year (Baker, 1974).

Some of the variables used in scheduling (Baker, 1974):

1. Processing time (t_j). the amount of processing required by job j.
2. Ready time (r_j). The point in time at which job j is available for processing.
3. Due date (d_j). The point in time at which the processing of job j is due to be completed.
4. Completion time (C_j). The time at which the processing of job j is finished.
5. Flowtime (F_j). The amount of time job j spends in the system.
   $$F_j = C_j - r_j \quad (1)$$
   Flowtime measures the response of the system to individual demands for service and represents the interval a job waits between its arrival and its departure.
6. Lateness (L_j). The amount of time by which the completion time of job j exceeds its due date.
   $$L_j = C_j – d_j \quad (2)$$
   Lateness measures the conformity of the schedule to a given due date, and it is important to note that the lateness quantity takes on negative values whenever a job is completed early.
7. Tardiness (T_j). The lateness of job j if it fails to meet its due date, or zero otherwise.
   $$T_j = max\{0, L_j\} \quad (3)$$
8. Slack (SL_i). which is a measure of the difference between the time ready for an assignment with a deadline and process time.
   $$SL_i = d_i – t_i \quad (4)$$
9. Makespan (M). The length of time required to complete all jobs.

Performance measure can be seen as follows:

- Mean flowtime:
  $$\bar{F} = \frac{1}{n}\sum_{j=1}^{n} F_j \quad (5)$$
- Mean tardiness:
  $$\bar{T} = \frac{1}{n}\sum_{j=1}^{n} T_j \quad (6)$$
- Maximum flowtime:
  $$F_{max} = max\{F_j\};\ 1 \leq j \leq n \quad (7)$$
- Maximum tardiness:
  $$T_{max} = max\{T_j\};\ 1 \leq j \leq n \quad (8)$$
- Number of tardy jobs:
  $$N_T = \sum_{j=1}^{n} \delta(T_j); \quad (9)$$
  where: $\delta(x) = 1$ if $x > 0$
  and $\delta(x) = 0$ otherwise

There are five methods used to solve problem. There are Generate and Test, EDD, Slack, Wilkerson Irwin, and LPT. EDD, Slack, Wilkerson Irwin, and LPT provide a feasible and good solution but not guarantee optimal solutions. Generate and Test is one of the enumeration method that guarantee optimal solutions. Generate and Test is the only method that considers machine setup time. If a machine will produce another product type then setup will conduct due to dies exchange. Setup time need an hour. We will choose the best method from five methods.

2.1. EDD Rule for reducing Maximum Tardiness on m Parallel Processors.

STEP 1: Sequence the tasks in EDD order.

STEP 2: Taking the tasks one at a time from the EDD list, schedule them on the processor with the least assigned time. Break ties arbitrarily.

2.2. SLACK for reducing Tardiness on m Processors

STEP 1: Sequence the tasks in SLACK order.

STEP 2: Taking the tasks one at a time from the SLACK list, schedule them on the processor with the least assigned time. Break ties arbitrarily.

2.3. Reduce Mean Tardiness on m Parallel Processors using Wilkerson Irwin Algorithm.

Conduct step 1 to step 3 for the SPT, EDD, and SLACK as initial priority rules. Select that schedule from step 3 with the least mean tardiness and implement.

STEP 1: Arrange the unscheduled tasks according to the initial priority rule.

STEP 2: Taking the tasks from the list one at a time, assign them to the processor with the least assigned time. Repeat step 2 until all tasks are assigned.

STEP 3: Take each processor separately and minimize the mean tardiness of those tasks assigned to it. This can be done using Wilkerson Irwin Algorithm.

2.4. Reduce Makespan as well as Mean Flow Times on m Processors using LPT.

STEP 1: Sequence the n tasks in LPT order.

STEP 2: Schedule each task from the LPT list to the processor that has the least time already assigned. Break ties arbitrarily.

STEP 3: After the tasks are assigned, reverse their sequence on each machine, putting the tasks on each processor in SPR order.

2.5. Generate and Test Algorithm

Search methods are widely used in various fields. Each quest has a specific purpose. The objectives should be formulated based on the situation and the measures of performance. This is an early stage of solving the problem (Russell, 2003).

There are four components to define the problem (Russell, 2003):

- Initial state, for the case of job scheduling on parallel machines, the initial state is not a single job are scheduled on a machine, and all machines ready time = 0.
- Possible actions, expressed by the successor function {(schedule job 1), (schedule job 2), (schedule job 3), ..., (schedule job n)}. The jobs are assigned to a machine with the smallest ready time.
- Testing objectives, determine what position to suit the objectives to be achieved. The purpose of this scheduling case all jobs have been scheduled.
- Path cost function, which measures the performance of the established schedule. In this study had more than one performance measures. The first priority is the total tardiness, and when several alternative schedules have the same total tardiness then use makespan as a second priority.

The problems that have been well defined will be solved. These can be done with the search tree. Starting from the initial state and using the successor function to find a new state space. This search can be illustrated by the graph in Figure 1. State space search process which is represented by the node data structure with the following five components (Russell, 2003):

- State: a state in the state space that shows the node in question.
- Parent - node: a node in the search tree that produces this node.

- Action: an action that is applied to the parent to generate the node.
- Path - cost: load, usually expressed as g (n), a path from the initial state to the node.
- Depth: the number of steps on a path from the initial state commonly referred to as levels.

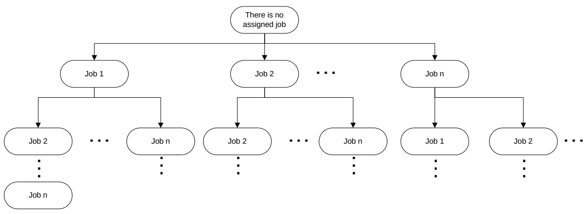

Figure 1. Search tree

There are two search strategies (Russell, 2003), the uninformed search / blind search and informed search / heuristic search. One search method with blind search strategy is depth - first search (DFS). DFS always expands the deepest node in the set until a successor is not selected (fringe). Once a node is expanded then the node is removed from the fringe, then the search back up to the shallowest node contained in the fringe. Variant of DFS is called backtracking search to reduce the memory usage by generating a successor for each stage.

In search of DFS , after reaching the deepest level but have not found a state that is the goal then will be looking to the smaller level (upward in Figure 1) . For the case of job scheduling these goals would be achieved when reaching the deepest level, which means the entire job has been scheduled. This means that the search process will be stopped with the lowest sequence number assignment job to job the biggest numbers. But not necessarily the path cost is optimal so that other alternatives need to be developed. How to generate alternative uses backtracking after reaching the deepest level, to find the next successor. Then do DFS back to earn a second alternative solution. This is done repeatedly until a successor is depleted or fringe is empty set. Way this generation is called Generate and Test. Generate and Test algorithm is a merger between DFS with backtracking, which is moving from the back leading to an initial state (Kusumadewi, 2005).

Generate and Test is one of the techniques that ensure optimal results, the algorithm which generating all combinations of existing and tested one by one, and then selected the best alternative solution. Generate and Test has two important procedures are:

- Generator (generate), which generate possible solutions.
- Test, which examine the solutions generated.

Generate and Test Algorithm in more detail:

1. Determine the initial state (initial state), which became a state node and current state at zero level.
2. Determine the set of nodes that can be selected at the next level (fringe: the set of successor / leaf nodes). If fringe form of an empty set then there is no solution to the sequence of nodes, then perform backtracking (step 5).
3. With reference to the DFS algorithm to select the first node of the fringe. Node is a current state to a new level. The selected nodes are removed from the fringe on the previous level.
4. Is the goal (Goal) is reached, namely: whether the sequence of nodes obtained can be the solution? If ' yes ' then:
   4.1. Calculate path cost.
   4.2. Is path cost < best path cost, if ' yes ' then the best path cost = path cost and best path = path (sequence of nodes obtained).
   4.3. Perform backtracking (step 5).
   If ' no' then repeat step 2.
5. Is the level equal to 0? If ' yes ' then present best path cost and best path then stop. If ' no' then do backtracking by moving to a node at the previous level and become the current state. Then do step 3.

3. RESEARCH METHOD

3.1. Data Collection and Processing

The list of firm order shown in Table 1

Table 1. The Firm Order October 3, 2012 until October 10, 2012

Job	Item	Quantity (unit)	Due Date
1	Damper Revo	40,000	30-Oct-12
2	Damper Suzuki Thunder	2,000	30-Oct-12
3	Damper Yamaha	180,000	24-Dec-12
4	Damper Suzuki Thunder	2,000	30-Oct-12
5	Damper Yamaha	40,000	31-Oct-12
6	Damper Kharisma	40,000	5-Nov-12
7	Damper Gb 4	40,000	5-Nov-12
8	Damper Suzuki	10,000	5-Nov-12

The processing time is shown in Table 2

Table 2. Process Time

Job	Item	Batch Size (unit)	Processing time/batch (min)
1	Damper Revo	42	10.35
2	Damper Suzuki Thunder	5	11
3	Damper Yamaha	51	13.594
4	Damper Suzuki Thunder	5	11
5	Damper Yamaha	51	13.594
6	Damper Kharisma	41	10.6
7	Damper Gb 4	61	10.875
8	Damper Suzuki	16	16.11

Different product type will use different mold. If any job which has a different product type to the job that is processed one step earlier, then require setup time by 1 hour to change the mold.

Table 3. Input Data for Scheduling

Job	Item	Quantity (unit)	Batch Size (unit)	Processing time/batch	Product Type	Due Date
1	Damper Revo	40,000	42	10.35	1	225.5
2	Damper Suzuki Thunder	2,000	5	11	2	225.5
3	Damper Yamaha	180,000	51	13.594	3	878
4	Damper Suzuki Thunder	2,000	5	11	2	225.5
5	Damper Yamaha	40,000	51	13.594	3	239.75
6	Damper Kharisma	40,000	41	10.6	4	295.5
7	Damper Gb 4	40,000	61	10.875	5	295.5
8	Damper Suzuki	10,000	16	16.11	6	295.5

3.2. Company Scheduling

Scheduling method applied by the company at this time is the first company to collect orders from customers for one week and will be scheduled on a single production next week. To see the sequence of job execution based on job which booked earlier. The schedule can be viewed on Table 4. Jobs with smaller number are the earlier jobs.

Based on the calculations have been done using the method of scheduling the company found that the total tardiness is equal to 1633.41 hours and makespan at 1147.16 hours.

Table 4. Company Scheduling

Job	Machine	Item
1	Trans 1	Damper Revo
2	Trans 2	Damper Suzuki Thunder
3	Trans 3	Damper Yamaha
4	Trans 2	Damper Suzuki Thunder
5	Trans 3	Damper Yamaha
6	Trans 1	Damper Kharisma
7	Trans 2	Damper Gb 4
8	Trans 3	Damper Suzuki

Table 5. Tardiness Calculation by Company Scheduling Method

Machine	Job	Due Date (hr)	Completion Time	Lateness (hr)	Tardiness (hr)
1	1	225.5	165.29	-60.21	0
	6	295.5	338.65	43.15	43.15*
2	2	225.5	74.33	-151.17	0
	4	225.5	147.66	-77.84	0
	7	295.5	267.51	-27.99	0
3	3	878	800.65	-77.35	0
	5	239.75	978.35	738.6	738.6*
	8	295.5	1147.16	851.66	851.66*

3.3. EDD

Table 6. Tardiness Calculation by EDD Method

Machine	Job	ti (hr)	Ci (hr)	di (hr)	Li (hr)	Ti (hr)
1	1	165.29	165.29	225.5	-60.21	0
	7	119.85	285.14	295.5	-10.36	0
2	2	74.33	74.33	225.5	-151.17	0
	5	178.7	253.03	239.75	13.28	13.28*
	3	799.65	1052.68	878	174.68	174.68*
3	4	74.33	74.33	225.5	-151.17	0
	6	173.36	247.69	295.5	-47.81	0
	8	168.81	416.5	295.5	121	121*
					Total	308.96

Based on the calculations have been done using the method EDD found that the total tardiness is equal to 308.96 hours and makespan at 1052.68 hours.

3.4. Slack

Table 7 Tardiness Calculation by Slack Method

Machine	Job	ti (hr)	Ci (hr)	di (hr)	Li (hr)	Ti (hr)
1	1	165.29	165.29	225.5	-60.21	0
	6	173.36	338.65	295.5	43.15	43.15*
	2	74.33	412.98	225.5	187.48	187.48*
	7	119.85	532.83	295.5	237.33	237.33*
2	5	178.7	178.7	239.75	-61.05	0
	8	168.81	347.51	295.5	52.01	52.01*
	4	74.33	421.84	225.5	196.34	196.34*
3	3	800.65	800.65	878	-77.35	0
					Total	716.31

Based on the calculations have been done using the method of Slack was found that the total tardiness is equal to the makespan of 716.31 hours and 800.65 hours.

3.5. Wilkerson Irwin

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Table 8. Tardiness Calculation by Wilkerson Irwin Method

Machine	Job	ti (hr)	Ci (hr)	di (hr)	Li (hr)	Ti (hr)
1	1	165.29	165.29	225.5	-60.21	0
	7	119.85	285.14	295.5	-10.36	0
2	2	74.33	74.33	225.5	-151.17	0
	5	178.7	253.03	239.75	13.28	13.28*
	3	799.65	1052.68	878	174.68	174.68*
3	4	74.33	74.33	225.5	-151.17	0
	6	173.36	247.69	295.5	-47.81	0
	8	168.81	416.5	295.5	121	121*
					Total	308.96

Based on the calculations have been done using the method Wilkerson Irwin found that the total tardiness is the makespan of 308.96 hours and hours at 1052.68.

3.6 Scheduling Methods LPT

Table 9. Tardiness Calculation by LPT Method

Machine	Job	ti (hr)	Ci (hr)	di (hr)	Li (hr)	Ti (hr)
1	3	800.65	800.65	878	-77.35	0
2	4	74.33	74.33	225.5	-151.17	0
	2	73.33	147.66	225.5	-77.84	0
	1	165.29	312.95	225.5	87.45	87.45*
	5	178.7	491.65	239.75	251.9	251.90*
3	7	119.85	119.85	295.5	-175.65	0
	8	168.81	288.66	295.5	-6.84	0
	6	173.36	462.02	295.5	166.52	166.52*
					Total	505.87

Based on the calculations have been done using the method LPT found that the total tardiness is equal to the makespan of 505.87 hours and 800.65 hours.

3.7. Scheduling With Generate and Test Algorithm

Diagram of generate and test for parallel machines scheduling algorithms can be seen in Figure 2.

Figure 3 shows the input on the Generate and Test program. Number 8 on the top left is the number of job, number 3 in the second column is the number of machines. In the second line job addressing the first, the third row is a second job, and so on. The first column shows the number of orders (units), the second column shows the size of the batch, the third column is the job processing time, the fourth column shows the type of job that is scheduled products, and the fifth column is the due date of each job.

In the Generate and Test method, job scheduling is done by assigning the job into machine that has smallest ready time. If there is more than one machines then assign to the machine that has smallest number.

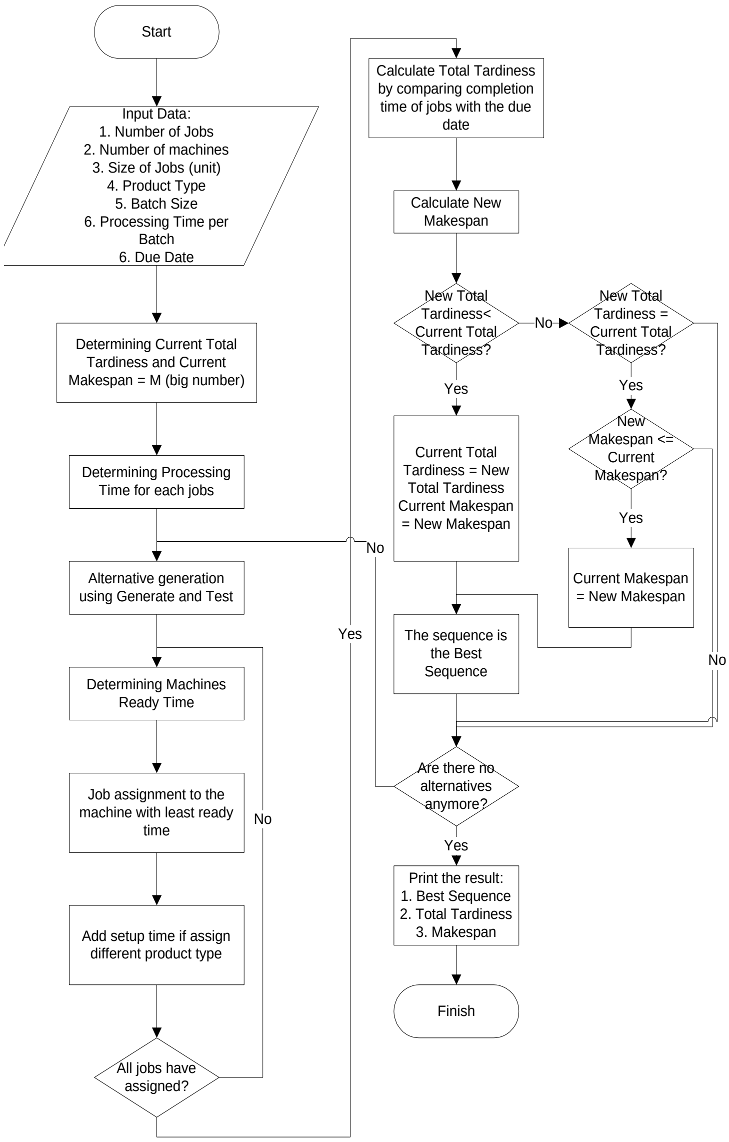


Figure 2. Diagram of Job Scheduling on Parallel Machines using the Generate and Test Algorithm

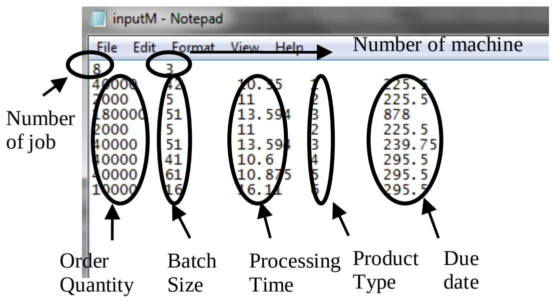
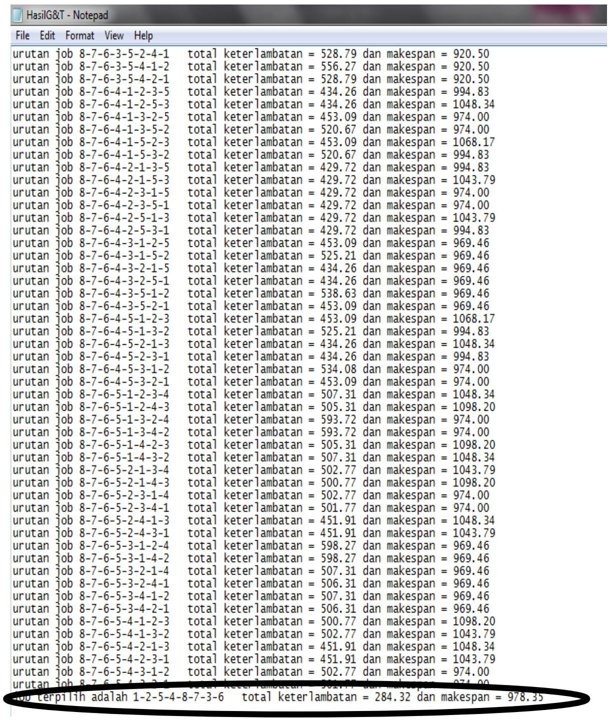


Figure 3. Input for Generate and Test

For example, if the first transfer machine, transfer machine 2, and 3 transfer machines have the same time the machine ready for zero hour, then the sequence are job 1 on machine 1, job 2 on machine 2, and job 3 on machine 3. For scheduling the next job will be scheduled based on the smallest ready time machine.



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HasilG&T - Notepad
File Edit Format View Help
urutan job 8-7-6-3-5-2-4-1   total keterlambatan = 528.79 dan makespan = 920.50
urutan job 8-7-6-3-5-4-1-2   total keterlambatan = 556.27 dan makespan = 920.50
urutan job 8-7-6-3-5-4-2-1   total keterlambatan = 528.79 dan makespan = 920.50
urutan job 8-7-6-4-1-2-3-5   total keterlambatan = 434.26 dan makespan = 994.83
urutan job 8-7-6-4-1-2-5-3   total keterlambatan = 434.26 dan makespan = 1048.34
urutan job 8-7-6-4-1-3-2-5   total keterlambatan = 453.09 dan makespan = 974.00
urutan job 8-7-6-4-1-3-5-2   total keterlambatan = 520.67 dan makespan = 974.00
urutan job 8-7-6-4-1-5-2-3   total keterlambatan = 453.09 dan makespan = 1068.17
urutan job 8-7-6-4-1-5-3-2   total keterlambatan = 520.67 dan makespan = 994.83
urutan job 8-7-6-4-2-1-3-5   total keterlambatan = 429.72 dan makespan = 994.83
urutan job 8-7-6-4-2-1-5-3   total keterlambatan = 429.72 dan makespan = 1043.79
urutan job 8-7-6-4-2-3-1-5   total keterlambatan = 429.72 dan makespan = 974.00
urutan job 8-7-6-4-2-3-5-1   total keterlambatan = 429.72 dan makespan = 974.00
urutan job 8-7-6-4-2-5-1-3   total keterlambatan = 429.72 dan makespan = 1043.79
urutan job 8-7-6-4-2-5-3-1   total keterlambatan = 429.72 dan makespan = 994.83
urutan job 8-7-6-4-3-1-2-5   total keterlambatan = 453.09 dan makespan = 969.46
urutan job 8-7-6-4-3-1-5-2   total keterlambatan = 525.21 dan makespan = 969.46
urutan job 8-7-6-4-3-2-1-5   total keterlambatan = 434.26 dan makespan = 969.46
urutan job 8-7-6-4-3-2-5-1   total keterlambatan = 434.26 dan makespan = 969.46
urutan job 8-7-6-4-3-5-1-2   total keterlambatan = 538.63 dan makespan = 969.46
urutan job 8-7-6-4-3-5-2-1   total keterlambatan = 453.09 dan makespan = 969.46
urutan job 8-7-6-4-5-1-2-3   total keterlambatan = 453.09 dan makespan = 1068.17
urutan job 8-7-6-4-5-1-3-2   total keterlambatan = 525.21 dan makespan = 994.83
urutan job 8-7-6-4-5-2-1-3   total keterlambatan = 434.26 dan makespan = 1048.34
urutan job 8-7-6-4-5-2-3-1   total keterlambatan = 434.26 dan makespan = 994.83
urutan job 8-7-6-4-5-3-1-2   total keterlambatan = 534.08 dan makespan = 974.00
urutan job 8-7-6-4-5-3-2-1   total keterlambatan = 453.09 dan makespan = 974.00
urutan job 8-7-6-5-1-2-3-4   total keterlambatan = 507.31 dan makespan = 1048.34
urutan job 8-7-6-5-1-2-4-3   total keterlambatan = 505.31 dan makespan = 1098.20
urutan job 8-7-6-5-1-3-2-4   total keterlambatan = 593.72 dan makespan = 974.00
urutan job 8-7-6-5-1-3-4-2   total keterlambatan = 593.72 dan makespan = 974.00
urutan job 8-7-6-5-1-4-2-3   total keterlambatan = 505.31 dan makespan = 1098.20
urutan job 8-7-6-5-1-4-3-2   total keterlambatan = 507.31 dan makespan = 1048.34
urutan job 8-7-6-5-2-1-3-4   total keterlambatan = 502.77 dan makespan = 1043.79
urutan job 8-7-6-5-2-1-4-3   total keterlambatan = 500.77 dan makespan = 1098.20
urutan job 8-7-6-5-2-3-1-4   total keterlambatan = 502.77 dan makespan = 974.00
urutan job 8-7-6-5-2-3-4-1   total keterlambatan = 501.77 dan makespan = 974.00
urutan job 8-7-6-5-2-4-1-3   total keterlambatan = 451.91 dan makespan = 1048.34
urutan job 8-7-6-5-2-4-3-1   total keterlambatan = 451.91 dan makespan = 1043.79
urutan job 8-7-6-5-3-1-2-4   total keterlambatan = 598.27 dan makespan = 969.46
urutan job 8-7-6-5-3-1-4-2   total keterlambatan = 598.27 dan makespan = 969.46
urutan job 8-7-6-5-3-2-1-4   total keterlambatan = 507.31 dan makespan = 969.46
urutan job 8-7-6-5-3-2-4-1   total keterlambatan = 506.31 dan makespan = 969.46
urutan job 8-7-6-5-3-4-1-2   total keterlambatan = 507.31 dan makespan = 969.46
urutan job 8-7-6-5-3-4-2-1   total keterlambatan = 506.31 dan makespan = 969.46
urutan job 8-7-6-5-4-1-2-3   total keterlambatan = 500.77 dan makespan = 1098.20
urutan job 8-7-6-5-4-1-3-2   total keterlambatan = 502.77 dan makespan = 1043.79
urutan job 8-7-6-5-4-2-1-3   total keterlambatan = 451.91 dan makespan = 1048.34
urutan job 8-7-6-5-4-2-3-1   total keterlambatan = 451.91 dan makespan = 1043.79
urutan job 8-7-6-5-4-3-1-2   total keterlambatan = 502.77 dan makespan = 974.00
job terpilih adalah 1-2-5-4-8-7-3-6   total keterlambatan = 284.32 dan makespan = 978.35
```

Figure 4. Output for Generate and Test

Figure 4 shows the result by using Generate and Test algorithm. We can see that the total tardiness is 284.32 hours and the makespan is 978.35 hours. The sequence is 1-2-5-4-8-7-3-6. This sequence indicated the priority that the jobs will be assigned into machine that has smallest ready time.

4. RESULT AND DISCUSSION

4.1. Result Comparison of Each Method

Table 10. Comparison Result of each Methods

Method	Tardiness (hr)	Makespan (hr)
Generate and Test	284.32	978.35
EDD	308.96	1053
Slack	716.31	800.65
Wilkerson Irwin	308.96	1052.68
LPT	505.87	800.65

The methods that we compared are EDD, Slack, Wilkerson Irwin, LPT, and Generate and Test. The result shows that Generate and Test method is a method which has smallest total tardiness with the amount of 284.32 hours and has makespan of 978.35 hours, so that the Generate and Test method can be used as the proposed method.

Heuristic methods (EDD, Slack, Wilkerson Irwin, and LPT) will not guarantee the optimum values, and the goal to be achieved is only to minimize the makespan or just minimize tardiness. Setup time has not been taken into consideration when determining the sequence of jobs to be scheduled. These can be solved using Generate and Test method. Moreover, the numbers of jobs that are scheduled are still under 15, so the sequence search process can be done quickly using the Generate and Test.

4.2. Comparison of Current Scheduling Method and Proposed Method

This section will compare tardiness and makespan between current scheduling method with Generate and Test method.

Table 11. Comparison of Results tardiness

Tardiness (hr)			
Current	Generate and Test	Delta	Decrease of Tardiness (%)
1633.41	284.32	1349.09	82.593

Table 12. Comparison of Results makespan

Makespan (hr)			
Current	Generate and Test	Delta	Decrease of Makespan (%)
1147.16	978.35	168.81	14.715

Scheduling method applied by the company at this time is the sequence of job execution be based on time of arrival of job. Job which come first will be assigned first without due date consideration. By not paying attention to these factors lead to the completion time becomes larger for some jobs and become tardy. Generate and test algorithms can be tailored to consider it. From tables of comparison, it can be seen that the tardiness decrease by 82.593% and makespan decrease by 14.715%.

5. CONCLUSION

From the data processing and analysis, it was concluded as follows:

1. Scheduling methods by the company can still be improved because:
    - The sequence only based on incoming order time. Job with early booked will be the first job in the sequence.

- Total tardiness is equal to 1633.41 hours and makespan at 1147.16 hours. These indicate still big enough relative to the Generate and Test result.

2. Proposed Scheduling Method
   - Generate and test scheduling method is able to accommodate a multi- objective problems easily.
   - Generate and test scheduling method capable to accommodate problems with setup times, which is directly involved in determining the job sequence.
   - Generate and Test for scheduling method can be done quickly when inputs number are no more than 15 jobs and scheduled on m parallel machines. The result is optimal with best total tardiness (positive lateness).
   - Total tardiness that produced by Generate and Test is 284.32 hours and makespan is 978.35 hours.
3. Company benefit by using the proposed method:
   - Tardiness reduces by 1349.09 hours or 82 593 %.
   - Makespan decreases by 168.81 hours or 14.715 %.

6. REFERENCES

(a) Baker, K. R. (1974) *Introduction to Sequencing and Sheduling*, John Wiley and Sons, New York.
(b) Bedworth, D.D., and Bailey, J.E (1982) *Integrated Production Control System: Management, Analysis, Design*, John Wiley and Sons, New York.
(c) Chase, R. B., Jacobs, F. R., Aquilano, N. J. (2004) *Operation Management for Competitive Advantage*, McGraw Hill, New York.
(d) Elsayed, E. A., Boucher, T. O. (1985) *Analysis and Control of Production Systems*, Prentice Hall, New Jersey.
(e) Kusumadewi, S. (2005) *Penyelesaian Masalah Optimasi dengan Teknik-teknik Heuristik*, Penerbit Graha Ilmu, Yogyakarta.
(f) Russell, S., Norvig, P. (2003) *Artificial Intelligence: A Modern Approach*, Prentice Hall, New Jersey.

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