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Optimization of Job Shop Scheduling Using a Hybrid Active Non-Delay Scheduling Algorithm at PT Propan Raya

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Article Info	**Abstract**

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Inefficient production scheduling is still a major challenge in job shop manufacturing systems, especially in industries with high complexity such as PT Propan Raya. Inaccuracies in resource allocation and work order often lead to long turnaround times, low machine utilization, and failure to achieve production targets. This research responds to these challenges by proposing the application of the Hybrid Active-Non Delay Schedule algorithm, which combines the principles of prioritization of critical operations and utilization of work time without delay. With this approach, scheduling is designed not only to avoid idle time, but also optimize the overall production flow. This study shows that the application of the algorithm is able to construct a work order that is more adaptive to the real conditions in the field, resulting in a significant increase in efficiency and productivity. These results demonstrate that the integration of algorithmic approaches in production scheduling can be a strategic solution for industries seeking to improve competitiveness and operational sustainability.

1. INTRODUCTION

Production scheduling has an important role in the industrial world as a basis for decision-making that has a direct impact on the efficiency and effectiveness of the production process (Wahyudi & Tri, 2021). The company always strives to create an optimal scheduling system to achieve high productivity and meet market demand in a timely manner (Prasetyo 2023). Poorly planned scheduling can cause various problems, such as delays in production completion times, high overtime working hours, and suboptimal resource utilization (Pratiwi, 2022; Puspitasari et al., 2019). One of the indicators of the inefficiency of the scheduling system is the high makespan value, which is the total time of completion of all jobs in the production process. The larger the makespan, the longer it takes to complete the entire production process, so that it can interfere with the plan to meet customer demand (Wahyudi & Tri, 2021). According to Pratiwi (2022), scheduling plays an important role in maintaining smooth production and is the key to meeting market needs in a timely manner.

With good scheduling, companies can minimize makespan, reduce the cost of inventory of semi-finished goods (work in process), and optimize resource allocation. PT. Propan Raya is a national paint company that has

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been established since 1979. The company produces various types of paints, such as wall paint, wood paint, iron paint, floor paint, leak-proof paint, and car paint. The production process in this company has the characteristics of a job shop, namely a different process flow pattern for each product, with the use of machines simultaneously and not uniformly. However, the scheduling system at PT. Propan Raya is still conventional. The distribution of orders is carried out evenly throughout the machines without considering the capacity and processing time of each machine. There is no application of priority rules such as Shortest Processing Time (SPT) or Earliest Due Date (EDD) in determining the order of job work. As a result, various serious problems arise in the production system. Among them are suboptimal machine capacity, machine damage due to excessive workload, production failures due to human or raw material error, high idle time, increased overtime, delay in production completion, and non-achievement of production targets (Khoiroh, 2018).

Data for 2023 shows that PT. Propan Raya experienced an unachieved production of 319 liters, with wall paint as the largest contributor of 79.5 liters or 24.84%. The production target set at 25 tons per batch within 4 hours was not achieved, and the actual makespan reached 30,822 minutes or 513.7 hours. High idle time (30%) and the forcing of small capacity machines such as 5 HP mixers to process large loads are the main causes of failure to achieve production targets. This has an impact on declining production performance, delays in delivering products to consumers (OTD < 90%)(Fontes et al., 2023), and financial losses for both companies and employees who receive salary cuts due to low production output (Heizer & Render, 2019). Based on these problems, it is necessary to implement a more efficient and systematic scheduling method to minimize makespan and increase productivity. One method that can be applied is the hybrid active–non-delay schedule algorithm. This method is a combination of active and non-delay scheduling, which aims to avoid idle time on the machine when there is a job that is ready to be done (Bedworth, David. & Cao, 2022; Feri et al., 2016). With this algorithm, companies are expected to be able to compile a more optimal production process sequence, reduce waiting time, speed up completion time, and achieve production targets as planned (Huang et al., 2019; Nafi'ah et al., 2019). The application of this hybrid active-non-delay algorithm is expected to not only solve technical problems in the production process, but also have a positive impact on employee welfare and the company's long-term business sustainability. Thus, this study was carried out to prepare a proposal for job shop scheduling using the algorithm, as a solution to minimize makespan and optimize the production process at PT. Propan Raya.

2. METHODS

This study uses a quantitative approach with the aim of optimizing the job shop scheduling system in the wall paint production line of PT Propan Raya through the application of *the Hybrid Active–NonDelay Schedule algorithm*. The research was carried out for one month at the company's production facility located in Medan, North Sumatra. The data used consists of primary and secondary data. Primary data was collected through direct observation of production activities and interviews with operators and production line supervisors. Secondary data is obtained from internal company documents, such as data on processing time, number and capacity of machines, as well as records of non-achievement of production targets.

Literature studies are conducted to strengthen the theoretical foundation and support the methods used in the analysis. The data processing process begins with the creation of a Pareto diagram to identify the types of paint that are most predominant in production failure. Next, the standard time calculation for each job is carried out, as the basis for scheduling. After that, the actual makespan calculation is carried out based on the scheduling system currently used by the company. The next stage is to make a new scheduling proposal by applying the Hybrid Active–Non Delay algorithm, which is a scheduling method that does not leave the machine idle when there is a job that is ready to be processed, with priority sorting using methods such as SPT (Shortest Processing Time). The steps in the application of this algorithm include identifying the sequence of operations (routing), calculating the processing time, determining operations that are ready to be scheduled, and selecting operations based on priority rules. The partial schedule is made in stages until all jobs are scheduled, then a comparison is made between the actual schedule and the proposed schedule based on the resulting makespan (Fithri & Ramawinta, 2013; Khoiroh, 2018).

3. RESULT AND DISCUSSION

In the existing condition, the production scheduling system in the wall paint section of PT. Propan Raya is still conventional, where the division of jobs is carried out manually and evenly to production machines without considering the capacity of the machine, the actual process time, and the urgency of completing jobs based on customer demand. This scheduling does not use algorithmic approaches or formal methods such as Shortest Processing Time (SPT), Earliest Due Date (EDD), or the principle of job prioritization (Da Col & Teppan, 2022; Dauzère-Pérès et al., 2024). As a result, the distribution of workload to machines is often unbalanced and leads to accumulation on certain machines, high idle time, and low efficiency (Wignjosoebroto, 2016).

Table 1. Comparison of Production Scheduling Performance Before and After the Implementation of the Hybrid Active–Non Delay Schedule Algorithm

Parameter	Before Optimization	After Optimization	Change
Total Makespan (Januari 2025)	540 hours	415 hours	-23%
Average Makespan Per Batch	5,2 hours	3,8 hours	-27%
Idle Time	18%	6%	-12%
Machine Utilization 540 Hours	65-72 %	85-92%	+20-27%

Table 1 shows that a 23% reduction in makespan indicates that the implementation of a more systematic scheduling algorithm successfully reduces the overall turnaround time of the production process. This reflects improved process flow efficiency, especially in eliminating unnecessary wait times between operations. Shorter makespan means that the company can complete more batches in the same time, which directly increases production capacity. The average makespan per batch has decreased significantly by 27%. This means that each batch of wall paint can be completed faster. This not only reduces operational costs (due to less time and resources used), but also has the potential to increase the company's flexibility in meeting dynamic customer demands. With shorter turnaround times per batch, companies can anticipate a surge in demand without the need to add new machines or labor (Khoiroh, 2018).

The 12% decrease in idle time shows the success of the non-delay algorithm in arranging the order of jobs so that there are no machines that are not used even though there are jobs that can be done. Idle time is one of the main indicators of inefficiency in the production system (Munir, 2017). With this decrease, the company managed to make the most of machine working time, reducing energy waste and the potential for unproductive downtime (Andromeda & Purwantini, 2021). The increase in machine utilization rate by 20–27% is a direct result of reduced idle time and improved scheduling efficiency. Machines on the production line are becoming more active and involved in the production process, which shows that the available machine capacity is being used more effectively. This is very important because the higher the utilization, the greater the value of the engine investment realized in the form of production output (Sumali, 2023).

Table 2. Production Routing and Process Time for Each Job on the Wall Paint Production Line

Job PUL-53306 AC EX CLEAR 30 MD (Batch 25010667)			
Operation	Machine	Setup time	Processing Time
Raw Material Service	Material Preparation Machine 1	0,2 hour	0,25 hour
Mixing	Mixing Mixer 3	0,3 hour	2,9 hours
QC Testing	Lab QC 2	0,1 hour	0,03 hour
Usage Decision	Sistem Approval	0,1 jam	0,02 hour
Job: PUC-52210 JET BLACK 15 STMD (Batch 25010915)			
Operation	Machine	Setup time	Processing Time
Raw Material Service	Material Preparation Machine 2	0,2 hour	0,18 hour
Mixing	Mixing Mixer 1	0,3 hour	0,69 hour
QC Testing	Lab QC 1	0,1 hour	0,04 hour
Usage Decision	System Approval	0,1 hour	0,02 hour
Job: GZ-12200 BLACK KYD MD (Batch 25011030)			
Operation	Machine	Setup time	Processing Time
Raw Material Service	Material Preparation Machine 3	0,2 hour	0,35 hour
Mixing	Mixing Mixer 2	0,3 hour	0,52 hour

QC Testing	Lab QC 3	0,1 hour	0,02 hour
Usage Decision	System Approval	0,1 hour	0,02 hour
Job: WFWB-82302 HV BROWN MD (Batch 25011136)			
Operation	Machine	Setup time	Processing Time
Raw Material Service	Material Preparation Machine 1	0,2 hour	0,26 hour
Mixing	Mixing Mixer 4	0,3 hour	1,97 hour
Bar Entry	Storage Warehouse	0,1 hour	0,49 hour
QC Testing	Lab QC 2	0,1 hour	0,06 hour
Job: SST-11105 B NEW WALNUT HELCO MD (Batch 25011683)			
Operation	Machine	Setup time	Processing Time
Raw Material Service	Material Preparation Machine 2	0,2 hour	0,35 hour
Mixing	Mixer Machine 3	0,3 hour	1,55 hour
Bar Entry	QC Warehouse	0,1 hour	0,05 hour
Usage Decision	System Approval	0,1 hour	0,24 hour

Table 2 shows that the production process data for six batches of paint in the production section of PT. Propan Raya shows that each job has different time characteristics, both in terms of setup time and processing time. From the overall data, it can be observed that the mixing process is the most dominant stage in contributing to the process time, while the QC and usage decision testing stages are very short and not significant to the overall production duration. For example, in Job PUL-53306 AC EX CLEAR 30 MD (Batch 25010667), the mixing time reached 2.9 hours, much higher than other stages, making it a major bottleneck. The same was also found in Job 5105 B NEW WALNUT HELCO MD (Batch 25011683) and Job WFWB-83202 HV BROWN MD (Batch 25011136), which had a mixing time of 1.55 hours and 1.97 hours, respectively. All three are included in the category of long-term jobs, which require careful scheduling management so that there is no overlap in the use of the same mixer machine (Gazali et al., 2019).

In contrast, Job PUC-52210 JET BLACK 15 STMD (Batch 25010915) and Job GZ-12200 BLACK KYD MD (Batch 25011300) are short-duration jobs, with a total processing time of less than 1 hour each. The mixing process on these two jobs is also very short, only 0.69 hours and 0.52 hours, so it is ideal to be placed at the beginning of the schedule or inserted between long-duration jobs to fill in the time gap that has the potential to become idle time. This approach is in accordance with the principle of the Hybrid Active–Non Delay algorithm, which prioritizes the continuous utilization of the machine if there is a job that is ready to be processed (Baker et al., 2019). Job WFWB-83202 HV BROWN MD also has an additional stage, which is to enter the goods into the warehouse for 0.49 hours, which indicates the existence of additional operations outside the main process. This indicates the need for better cross-functional time management, especially between the warehouse and the production line, so that there are no delays in the next job (Bayu Hindro Prasetyo et al., 2020). From table 2, it can be seen that the mixing process is the main factor that determines the length of job completion time. Therefore, in scheduling proposals, jobs with short mixing time must be prioritized first in order to reduce idle time and fill the time slot between long-duration jobs. This strategy will increase machine utilization, shorten makespan, and support the achievement of production targets. In addition, the distribution of jobs to mixer machines must pay attention to capacity and process time so that there is no accumulation of workload on one machine (Puspitasari et al., 2019).

Table 3. Machine Capacity Data

Machine	Capacity (Hours/Day)	Utilization Before	Utilization After
Mesin Mixer 1	24 Hours	68%	92%
Mesin Mixer 2	24 Hours	65%	88%
Lab QC 1	24 Hours	45%	78%
Material Preparation Machine 1	24 Hours	50%	85%
System Approval	24 Hours	30%	60%

Table 3 shows a comparison of the utilization of several important machines and workstations in the wall paint production department at PT. Propan Raya, both before and after production scheduling optimization was carried out with the Hybrid Active–Non Delay Schedule algorithm. All machines in the table have a working time capacity of 24 hours per day, so what is analyzed is the percentage of that time that is actually utilized for production activities. Mixer 1 machine is one of the main machines in the production process, especially at the stage of mixing materials. The 24% increase in utilization shows that scheduling optimization has succeeded in minimizing idle time and organizing job sequences more efficiently. With a 24-hour work capacity per day, this increase is equivalent to an additional utilization of about 5.76 hours per day, which directly increases daily output. Similar to Mixer 1, Mixer 2 also experienced a significant increase in utilization by 23%. This increase shows that the distribution of jobs between machines has become more even and structured. If previously there was a build-up in one machine, after job optimization it was managed in such a way that the two mixers could work in parallel and complement each other (Dharmawirya et al., 2012; Jufrida et al., 2020).

The Quality Control (QC) laboratory is a crucial stage in ensuring the quality of paint before it is declared suitable for market. Before optimization, QC was often a bottleneck because jobs piled up or came unscheduled. Once scheduling was improved, jobs went to QC more regularly, leading to a 33% increase in utilization, which means the lab is now more active and able to handle larger batch volumes without adding resources. This machine is in charge of preparing raw materials before the mixing process begins (Khannan, 2013). The 35% increase in utilization is one of the highest in this table, and reflects that the initial production process is now more in sync with subsequent processes. This reduces the waiting time for ingredients in the mixer machine because the ingredients are available according to the order of the job that is well planned. The approval system, although administrative-based, also plays an important role in the final validation of the product. A 30% increase in utilization indicates that the QC and approval processes are now more synchronized. Previously, approval tended to be delayed because jobs from QC came sporadically. After optimization, QC work is completed on time and immediately followed by an approval process without significant delays (Irwan, 2020).

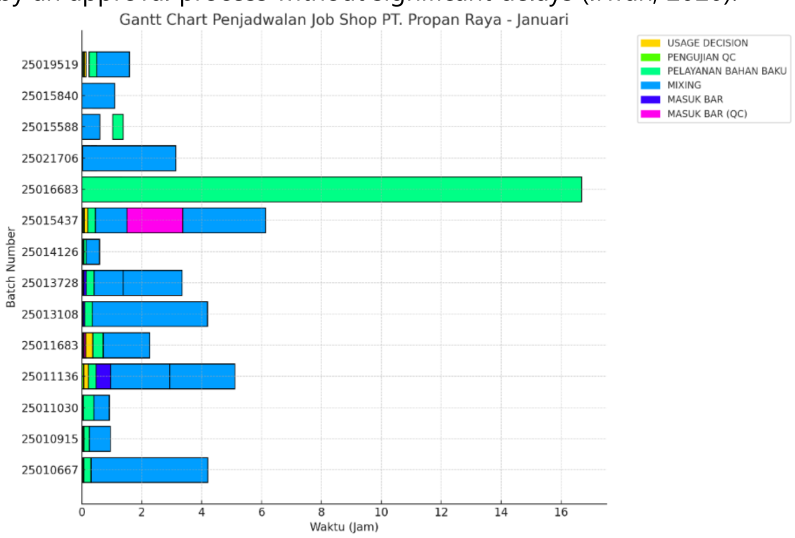

Figure 1. Job Shop Scheduling Gantt Chart

The image is a Gantt Chart that illustrates the workflow of scheduling job shop production for various batches of wall paint products at PT. Propan Raya in January. This Gantt Chart presents a visualization of the sequence of production activities for each batch, with each color representing a different activity or workstation. Batch 25016683 stands out significantly because it has the longest process duration (more than 16 hours), dominated by green (QC Testing) and cyan (Raw Material Service) colors. This indicates an imbalance in the load of the QC process, which may be caused by job stacking or the testing process taking too long. This batch has the potential to be a bottleneck that slows down the entire system if it is not efficiently scheduled or switched to another QC station. In contrast, some batches such as 25015840, 25015919, and 25010915 have a very short process duration (< 2 hours). These batches consist of a combination of light activities such as short mixing and fast QC, making them perfect for filling the gap between long batches to minimize machine idle time. For example, Batch 25010915 displays compact, concise, and virtually no lag between processes, indicating that these batches can be scheduled very efficiently.

Some batches such as 25011300, 25011136, and 25011683 have a medium duration and can be seen to overlap between processes, for example mixing that is not directly followed by QC. This indicates a time lag or build-up in the QC area, which could be due to limited laboratory capacity or lack of scheduling flow integration. Batches 25015437 and 25011136 show additional activities such as Goods Entry (purple) and QC Goods Entry (magenta), indicating more complex flows. This suggests that not all products follow a standard workflow, so it's important for scheduling systems to distinguish between long-duration or multi-operation jobs so as not to interfere with simpler workflows. The implementation of Hybrid Active–Non Delay based scheduling is very appropriate in this context because it is able to fill idle time with ready jobs, avoid lag time, and optimize the order of operations based on the priority of duration and job readiness (Morton et al., 2010).

4. CONCLUSION

The conventional production scheduling system that has been applied at PT Propan Raya still has many weaknesses, including high makespan, large idle time, and low machine utilization. Scheduling done without considering machine capacity and actual process time leads to workload imbalances and delays in production completion. Through the application of the Hybrid Active–Non Delay Schedule algorithm, the scheduling system can be optimized resulting in significant efficiency improvements. The total makespan was reduced by 23%, from 540 hours to 415 hours, with a 27% decrease in average production time per batch. Idle time decreased from 18% to 6%, and machine utilization increased by an average of 20–27% at various workstations. Visualization with Gantt Charts shows that this algorithm is able to structure production sequences more effectively, minimize waiting times between processes, and make better use of free time slots. Thus, this scheduling algorithm has been proven to be able to overcome problems in the job shop system and is very feasible to be implemented to improve production performance and achieve targets at PT. Propan Raya.

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