Implementation of a Decision Tree Model to Optimize Production Allocation of Corrugated Zinc Roofs at PT Yane Manufaktur Indonesia

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***Abstract*—This study develops an efficient decision-making algorithm for production scheduling and operator assignment at PT Yane Manufaktur Indonesia. The primary challenge involves optimizing resource allocation across two parallel workflows, the Forming Process and the Shearing & Bending Process, considering various machine capacities, speeds, power consumption, and operator requirements. Implementing Discrete Mathematics principles, the algorithm utilizes a hierarchical decision tree to process incoming orders systematically. It integrates calculations for Estimated Time Completion (ETC) and power consumption, guiding resource allocation based on machine and operator availability. Implemented in Python, this algorithm offers a framework for PT Yane Manufaktur Indonesia to enhance operational efficiency, optimize machine and operator utilization by minimizing idle time and bottlenecks, and facilitate structured data-driven strategic decisions. Consequently, this research enriches scientific literature on applying Discrete Mathematics concepts in manufacturing scheduling and resource allocation.**

Keywords*— *Decision Tree; Production Scheduling; Resource Allocation; Manufacture Industry

I. Introduction

The Industrial Revolution 4.0, characterized by the widespread adoption of modern technologies in every economic activity, from production to consumption, has created a highly competitive environment in the industrial sector, particularly in the manufacturing industry. In this era, companies are required not only to produce high-quality products but also to optimize their production processes as a key strategy to maintain competitiveness in the market. However, achieving this optimization created a challenge, as it relies heavily on effective production scheduling and smart resource allocation. Without careful planning, potential inefficiencies such as machines that have been idle for too long, work backlogs, or late deliveries can hamper the Company's overall performance [1].

PT Yane Manufaktur Indonesia is a manufacturing company that has specialized in producing corrugated metal roofing and wall panels in Indonesia since 2013. The Company's commitment to product quality is demonstrated by its achievement of ISO 9001:2015 certification from Lloyd's Certification Institution in January 2016, making PT Yane Manufaktur the first metal roof and wall manufacturing company in Indonesia to attain this standard. PT Yane Manufaktur Indonesia offers a variety of roof profile products, including Yane 600, Yane 650, Yane 672, Yane 750, Kabe 325 (Flat, Rib, Wavy), and SD 680, made from Zincalume, Colorbond, and Kirana materials. The production process is also supported by precision forming machines from Japan and bending machines from Switzerland, further strengthening the Company's position in producing strong and durable products [2].

Fig. 1. Front Looks at PT Yane Manufaktur Indonesia

The Company's potential for sustainability in dealing with increasing workloads over time indicates the need for an advanced strategy design to anticipate future demand growth. The main production processes in the factory can be classified into two separate workflows that can run simultaneously: the Forming Process and the Shearing & Bending Process. The Forming Process involves processing material coils into aluminum-zinc plates with specific profiles, such as Yane 600, Yane 672, and Yane 750, using various forming machines. Meanwhile, the Shearing & Bending Process workflow involves cutting the coil plate using a shearing machine, followed by the plate bending process using a bending machine. Complexity arises from the variation in capacity, speed, and power consumption of the machine, as well as the needs of operators in each process, making daily scheduling decision-making a challenge that requires a systematic approach to optimize the use of existing resources and minimize waiting time.

Discrete Mathematics plays a crucial role in formulating solutions to discrete scheduling and resource allocation problems like this. The concepts in Discrete Mathematics allow the modelling of production entities, such as machines, operators, and orders, as discrete elements that can be managed in a structured manner. In this paper, the author will design a series of decision-making algorithms based on the principles of Discrete Mathematics to ensure efficiency and correctness. The topic that will serve as the primary foundation for this paper is the Decision tree, which is highly relevant due to its ability to formulate Decision-making logic hierarchically and clearly, based on a series of choices that branch according to specific conditions.

Reflecting on the field conditions and problems underlying the making of this paper, this study will have the primary objective of designing an efficient decision-making algorithm for machine work scheduling and operator assignment at PT Yane Manufaktur Indonesia. This algorithm will focus on key variable considerations, including production time efficiency based on the speed of each machine, the efficiency of electrical power consumed by each machine, and the working hour limits of factory employees as machine operators. The contribution of this study is expected to provide practical benefits for PT Yane, enabling improved operational efficiency and more structured, data-driven strategic decisions, as well as enriching the scientific literature on the application of Discrete Mathematics concepts in the manufacturing industry.

II. Theoretical Framework

A. *Manufacturing System in PT Yane Manufaktur Indonesia*

Manufacturing, as described in [6], is a branch of industry that focuses on the application of machines, equipment, and labor in a process medium to transform raw materials, components, or other parts into finished goods that meet specific specification standards. The manufacturing industry is generally capable of producing on a large scale. Some of the characteristics of manufacturing companies include:

1. *Material Processing and Production Results. Manufacturing companies focus their work on the scope of processing raw materials into finished products, whose results can be seen by the eye (products have a form), so that they can be distinguished from service companies, whose products are not tangible objects.*
2. *Large Machines and Scale. The production process of manufacturing companies typically utilizes machine setups and human labor, with a division of labor employed in large-scale production.*
3. *There are Production Costs. The production costs required comprise three components: raw material costs, labor costs, and factory overhead costs (FOH).*

In a manufacturing industry business system, several processes are also required to support the operation of the production process and the administration of a company. According to [6], business processes in the manufacturing industry can be classified into six processes that move sequentially or simultaneously, including:

1. *Procurement Process,* a business process related to the procurement of goods and other materials necessary to support the factory's operational continuity, including raw materials, spare parts, medical devices, cleaning tools, building and employee supplies, and carpentry tools.
2. *In-Out Inventory,* a process that handles the entry and exit of goods in the factory, considering the business process that involves a significant amount of processing raw materials into ready-to-use products. As a result, a significant amount of goods and materials will be entering and leaving the company. This process will be the key to controlling the flow of these goods.
3. *Production Process,* the process of making raw materials into finished goods that are ready to be sold to consumers. In practice, there are more specific divisions tailored to the industry's needs, for example, the PPIC (Production Planning and Inventory Control) and QC (Quality Control) divisions.
4. *Sales and Marketing,* the process is used to achieve the goals of the production process, specifically by selling goods produced by the manufacturing company to generate a profit.
5. *Administration and General,* the process of determining policies, directing, and supervising all company activities to ensure that production processes and company administration can continue to run effectively and efficiently.
6. *Accounting and Finance,* a process that functions always to ensure the company's financial condition remains healthy and able to meet all production needs, as well as control over debt and tax payment responsibilities to the government.

PT Yane Manufaktur Indonesia, as a manufacturer of high-quality corrugated roofing and walls, has integrated various technologies and procedures to meet industry standards. The company was founded in 2013 and obtained ISO 9001:2015 certification from Lloyd Certification Institution in January 2016, becoming the first metal roofing and wall company in Indonesia to receive the certification. The products produced by PT Yane Manufaktur Indonesia include various roof, cladding, and ceiling profiles, as well as supporting accessories [2].

The main raw materials used include Zincalume, Colorbond, and Kirana. Zincalume consists of 55.0% aluminum, 43.5% zinc, and 1.5% silicon, with a minimum coating mass of $150 g/m^2$. Colorbond uses aluminum-zinc alloy coated steel with the BlueScope paint system. Kirana is precast coated steel from ABADI substrate with a yield strength of G550 & G300 and a nominal gloss level of 30%. The production process is supported using forming machines from Japan and bending machines from Switzerland [3].

The production process at PT Yane Manufaktur Indonesia is categorized into two main workflows: Forming Process and Shearing & Bending Process. Both workflows operate independently and can run simultaneously on different machines. This separation of workflows allows parallel production, where stages in one process do not have to wait for the completion of stages in the other process, except for the need for initial materials.

a) Forming: The stage of forming the corrugated zinc roof profile. This workflow begins with the installation of a coil of *material into the forming machine. The machine then presses the coil, forming it into an aluminum-zinc plate with a predetermined wave profile. The forming process speed varies between 16 to 25 meters per minute. This speed variation depends on the type of material and thickness used, as each combination requires specific machine settings to meet output standards. At PT Yane Manufaktur Indonesia, the forming machines are named according to the corrugated zinc roof profile produced (Yane600, Yane750, Yane650, Yane672, Kabe325Flat, Kabe325Rib, Kabe325Wavy, and SD680).*

Fig. 2. Forming Machine in PT Yane Manufaktur Indonesia

b) Shearing and Bending: The production stage of roof accessories requires cutting and bending of plates. The bending stage begins with cutting the coil plate according to the design using a shearing machine. The cut plate is then transferred to the bending machine with two different length capacities available, 4 meters and 6.4 meters. The operational characteristic of this bending machine is its ability to bend in only one direction (from bottom to top). If the design requires bending in the opposite direction, the operator must manually turn the zinc plate, which contributes to the variation in time per bend. The time for each bend is estimated to be between 3 to 5 seconds. The bending machine's electrical power is 3-phase, 3x400V, 14A, 50Hz.

Fig. 3. Bending Machine in PT Yane Manufaktur Indonesia

B. Tree

Referring to [4], a tree is an undirected graph that is connected and does not contain a circuit (cycle). A graph can be a tree if it is an undirected graph; every vertex of the graph is connected, and it does not have a circuit. Trees are generally used to support a series of logical schemes and decision-making processes to calculate routes and path lengths in a network.

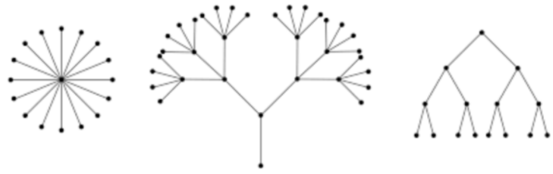

Fig. 4. Various Examples of Tree

As explained in [4], trees have several binding properties. If we have a graph $G = (V, E)$, which is a simple undirected graph, and the number of vertices is n, then all the statements below are equivalent:

1. G is a tree.
2. A single path connects each pair of vertices in G.
3. G is connected and has $m = n - 1$ edges.
4. G does not contain a circuit.
5. G is connected, and all its edges are bridges.

A tree in which one vertex is designated as the Root and its edges are assigned a direction, thereby forming a directed graph, is called a rooted tree. The following is an example of a tree and two rooted trees resulting from selecting two different vertices as roots [5].

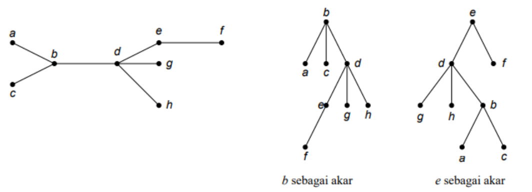

Fig. 5. Example of Rooted Tree with Two Different Chosen Root

In a Rooted Tree, there are several terminologies commonly used to describe some components in a Rooted Tree, including:

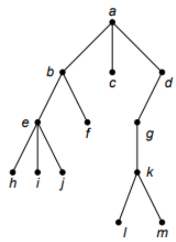

Fig. 6. Example of Rooted Tree

a. **Node/Vertex**, an element that can represent data and has a relationship between one Node and another. Example: a, b, c, d, m, l are Nodes in Fig. 6.
b. **Side/Edge**, an element that represents the relationship between 2 Nodes. Example: E(a, b) and E(k, m) in Fig. 6.
c. **Parent**, a Node that has branches to other Nodes. Example: e is the Parent of h, i, j in Fig. 6.
d. **Child**, a Node that has branches to the Node. Example: c is the Child of A, and k has Children, namely l and m, in Fig. 6.

e. **Root**, the central Node in the tree that does not have a Parent. Each Rooted Tree only has one Root. Example: a is the Root in Fig. 6.
f. **Leaf**, a Node that does not have a Child. Example: h, i, j, l, m, f, c in Fig. 6.

C. Decision-Making Algorithm

One form of application of the Rooted Tree is reflected in the concept of the Decision Tree. A decision tree is a prediction model that makes use of a hierarchical tree structure [7]. The primary benefit of using a decision tree is for its ability to break down complex decision-making processes into simpler ones, making it easier for decision-makers to solve problems and identify the most efficient and appropriate solutions. Additionally, a decision tree can be used to define the relationship between multiple information variables and a marked variable, making it a valuable initial step in modeling a system.

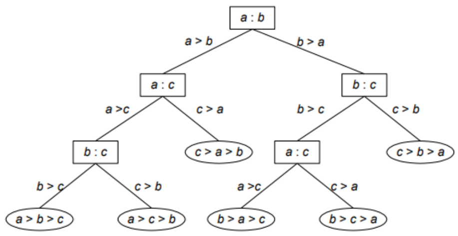

Fig. 7. Simple Sorting Algorithm of Three Elements Using Decision Tree

The decisions produced by a Decision Tree can be categorized into two types: Single Stage and Multiple Stage. Single Stage refers to a decision that is final and does not become the basis for other choices in the future. Meanwhile, Multiple Stage explains a decision condition that is classified as a dependent decision (depending on the next decision-making stage) [7].

III. DECISION ALGORITHM

In this section, the decision-making algorithm for optimizing production efficiency by considering different resource limitations and production demands will be explained using decision tree principles, facilitating structured and adaptive decision-making in response to production dynamics.

A. Problem Modeling Approach

The core problem in this study is the scheduling of machine work and operator assignment to meet the production demand of metal roofs and accessories at PT Yane Manufaktur Indonesia, which has not been studied technically. This problem can be classified as a discrete resource allocation problem with time constraints, where several orders must be processed through two main workflows that can run in parallel: the Forming Process and the Shearing & Bending Process. Each workflow has different machine characteristics in terms of production speed, power consumption, and operator requirements. The goal of this improvement is to minimize the total order completion time and improve the utilization of electrical power while ensuring the efficient use of human resources within the constraints of available working hours.

To simplify the complexity of the problem and allow for focused modeling, several key assumptions are made in this study:

- The entire roof and accessories production process is assumed to be carried out within the PT Yane Manufaktur Indonesia factory facility, so the algorithm will not consider on-site forming decisions or external logistics aspects such as transportation route selection.
- The available forming machines are assumed to be only three, namely, the Yane 600, Yane 672, and Yane 750. Therefore, the job scheduling for the forming task will only be assigned to these three forming machines and will be ignored for the forming machines of other wave types.
- The workload received by the factory is assumed to have a consistent pattern every two weeks, reflecting the last two weeks' work summary data available. This assumption allows the use of historical data as a basis for recurring demand scenarios.
- The forming machine speed listed in the range (16-25 meters per minute for Yane672 and Yane750) will be simplified to an average value of 20 meters per minute for calculation purposes in the algorithm. Meanwhile, the speed for the Yane600 machine will be set to a fixed value of 16 meters per minute. The original speed variation is assumed to be caused by differences in machine settings based on material type and thickness.
- The time required for each bend on the bending machine will be assumed to be an average of 4 seconds per bend, although manual data shows a range of 3-5 seconds. This variation comes from the need for operators to flip the zinc plate if two-way bending is required.
- Operator flexibility is considered high. Each operator is assumed to have the ability to operate all forming machines (Yane 600, Yane 672, Yane 750) and can switch between shearing and bending workflows. This allows for a pool of operators that can be allocated as needed.
- In the context of daily scheduling, the algorithm will assume the assignment of operators in a relatively fixed daily rotation for each machine or work team. Still, the operator's flexibility capability will be considered as a load-balancing mechanism or bottleneck handling if necessary.
- Effective working hours per day for employees and machine availability are assumed to be by factory operational standards, which are eight working hours per day.

Based on these assumptions and internal data from PT Yane Manufaktur Indonesia regarding human resources and the capacity of each machine based on the data shown in the following Table I,

TABLE I. MACHINE CAPACITY

Type	Speed	Power	Operator (people)
Yane600	16 m/minutes	3phase, 380VAC, 30A, 11kW	1
Yane672	20 m/minutes	3phase, 380VAC, 30A, 16.5kW	1
Yane750	20 m/minutes	3phase, 380VAC, 30A, 9.5kW	1
Bending	20 m/minutes	14A, 9.7kW	2

then the algorithm will receive several input variables based on the client's request consisting of,

a. type of roof profile and/or accessories ordered;
b. material thickness (BMT);
c. total length of the order; and
d. specifications and the number of accessories ordered (if accessories are included).

B. Decision Tree Structure

This decision-making algorithm will be structured like a decision tree, where each Node represents a situation or question, and each branch represents the result of the condition that directs the next decision-making step. This structure allows for systematic order processing, from initial identification to optimal resource allocation.

Based on the existing data and assumptions that have been made to narrow the research space, a decision tree is designed with Nodes that represent decisions that must be taken and Edges as branches connecting Parent Nodes with their Child based on the decisions taken with the following Decision Tree structure specifications:

1) Node 1: Flow Classification

The initial step in the algorithm is to classify each incoming order based on the type of product requested by the client [input variable a]. This decision Node serves as the main gate that separates orders into two different production workflows at PT Yane Manufaktur Indonesia.

Logic:

- If the type of roof profile ordered is a corrugated roof profile (Yane 600, Yane 672, Yane 750, SD 680, or Kabe 325), then the order will be directed to the forming process workflow.
- If the order is an accessory that requires cutting and bending, then the order will be directed to the shearing & bending Process workflow.

Branch: The output of this Node directs the order to the relevant decision subtree for the forming, shearing, and bending workflow.

2) Node 2: (Forming) Machine Identification and Roof Production Time Calculation

Once an order is classified into the forming workflow, this Node identifies the specific forming machine type required and calculates the estimated time needed to complete the order.

Logic:

- Based on the type of roof profile ordered, the corresponding forming machine will be identified (e.g., an order for Yane 600 profiles can only be processed by the Yane600 machine).
- The production speed of the relevant machines will be as follows: 16 meters per minute for the Yane600 and an average of 20 meters per minute for the Yane672 and Yane750.
- The Estimated Time Completion (ETC) for this order will be calculated using formula (1):

$$ETCForming = \frac{Total\ Order\ Length\ (meter)}{Machine\ Speed\ (meter/menit)} \quad (1)$$

- This process requires one operator per machine.

Branch: The results of the ETC calculation and machine identification will be forwarded to the Node responsible for checking resource availability.

3) Node 3: (Shearing & Bending) Accessories Production Time Calculation

If the order is classified as accessories, this Node will calculate the estimated time required based on the accessory specifications and the number of bends.

Logic:

- Based on the accessory specifications and the number of accessories ordered, the Total Number of Bends required for the entire accessory order will be calculated.
- Estimated Time Completion (ETC) for the bending process will be calculated using the formula (2):

$$\text{ETCBending} = \frac{\text{Total Bending} \times 4}{60}\ minutes \quad (2)$$

- The operator team requirement for the shearing & bending workflow is two operators for shearing, one operator for the forklift, and two operators per bending machine used. Bending machines are available in 2 units.

Branch: The ETC results and operator/team requirements will be forwarded to the resource availability check Node.

4) Node 4: Machine availability check

This Node is responsible for checking whether the machines required for the order (both forming and shearing & bending) have free capacity and are available within an 8-hour workday schedule.

Logic:

- Identify the Machine_Type, ETC required from Node 2 or Node 3.
- Check the relevant machine schedule to ensure there are sufficient time slots for ETC within the available working hours on that day.

- For the Yane600 Machine (having two units) or the Bending Machine (having two units), the algorithm will find the most suitable unit to allocate (i.e., the least loaded unit at that time).

Branch: If the machine is available, the flow continues to check operator availability. If not available, the flow goes to the conflict handling Node.

5) Node 5: Operator Availability Check

This Node ensures that the number of operators required to run the machine or process is available from the total pool of operators.

Logic:

- Get Operator_Requirement from Node 2 or Node 3
- Compare the Operator_Requirement with the number of operators still available from the total of 10 operators after checking if operators are already assigned to other jobs at the same time or not.
- Since operators can handle all jobs and can swap positions, this check is done on the entire operator pool. It is essential to note that one operator can only be assigned to one stage at a time.

Branch: If the operator is available, the order can be allocated. If not, the flow leads to the conflict-handling Node.

6) Node 6: Conflict Handling

This Node becomes a leaf of the Decision Tree, handling dependent decisions in the production workflow optimization algorithm. Node 6 allows the queue to be shifted on that day. If the input is labeled as urgent, the system will automatically schedule the input for the next working day.

7) Node 7: Final Decision

This Node becomes a leaf of the Decision Tree in the PT Yane Manufaktur Indonesia production workflow optimization algorithm. Node 7 will,

1. assign the order to the selected machine;
2. allocate the required operator;
3. record the start & end times; and
4. calculate the power consumption with the formula (3):

$$Power = Machine\ Power\ (kW) \times \text{ETC (hour)} \quad (3)$$

C. Decision Tree and Code Implementation

With all the information, conditions, and assumptions that have been considered, the following are the results of creating a Decision Tree based on the explained structure.

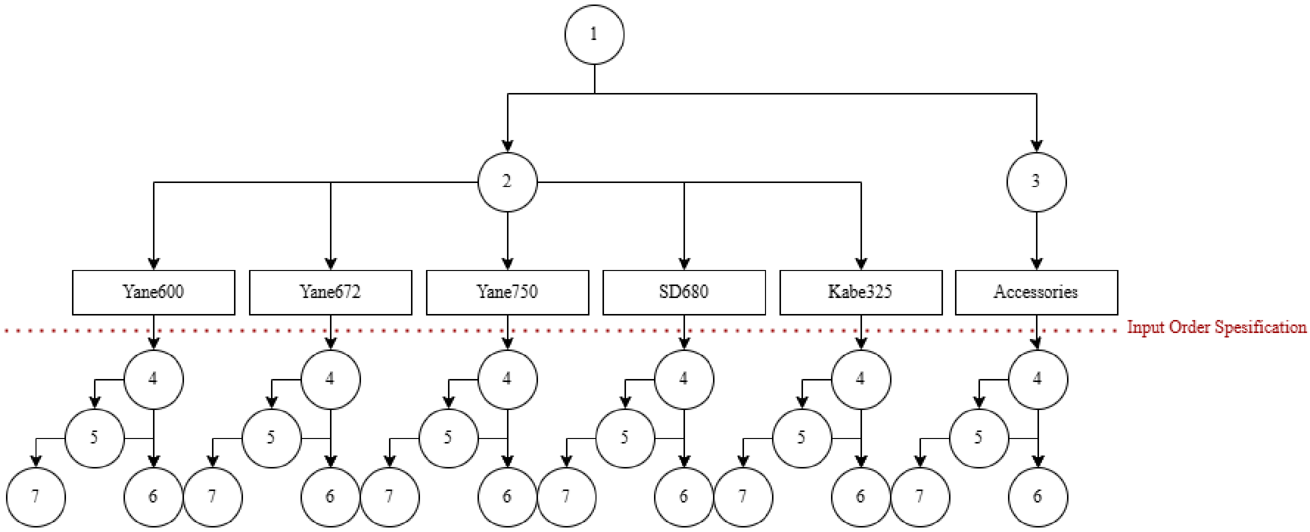

Fig. 8. Decision Tree for Optimized Production Allocation of Corrugated Zinc Roofs at PT Yane Manufaktur Indonesia

In addition, the implementation of the decision tree has been made in a simple terminal-based I/O program written in Python, which simulates the decision-making flow according to the decision tree shown in Fig. 8. The program can be accessed by clicking this link.

IV. Conclusion

Based on the research conducted, the researcher has concluded that the developed algorithm adopts a decision tree structure as a decision-making framework, which has been successfully created. The approach used in this study enables systematic order processing, beginning with the classification of product types (roof profiles or accessories), identifying the appropriate machines, and verifying the availability of machine and operator time slots. Each Node in the decision tree guides the process flow based on specific conditions, such as order volume, priority, and resource status. The Estimated Time Consumption (ETC) and power consumption calculation functions have been integrated into the algorithm. The implementation of the algorithm in Python code demonstrates how machine allocation decisions and operator assignments can be simulated logically, yielding a detailed production schedule for each order.

From a practical benefit perspective, the design of this algorithm is expected to provide significant contributions to PT Yane Manufaktur Indonesia. First, this algorithm provides a framework to enhance operational efficiency by optimizing machine utilization and operator allocation, thereby minimizing idle time and potential bottlenecks. Second, by providing structured and data-driven decision-making, management can make more effective and responsive production planning in response to client demand. The ability to predict job duration and power consumption also allows PT Yane to manage resources more predictively and strategically.

Scientifically, this study enriches the literature on the application of Discrete Mathematics concepts in the manufacturing industry domain, especially in production scheduling and resource allocation problems. The use of decision trees as the core of the algorithm demonstrates how discrete mathematical structures can be applied to solve complex real-world problems that require decisions to be made based on a series of logical conditions. This contribution confirms the relevance of Discrete Mathematics in developing optimization solutions to industrial operational challenges.

Although this algorithm has been designed to handle PT Yane's production scenario with explicit assumptions, several areas can be explored for future development. This includes integration of material inventory management, handling of unexpected machine breakdowns, and the application of more sophisticated optimization methods to find the optimal global schedule.

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