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Constructing an Automotive Plastic Components Production Line Based on Tecnomatix Plant Simulation Software using SimTalk and SQLite

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A B S T R A C T

Information management using information technology in the production of industrial machinery systems plays a crucial role in optimizing production processes and enhancing the efficiency of industrial plants, particularly in automotive plastic component production lines. Therefore, in this research, information technology is applied in information management by implementing a monitoring system designed within the Technomatix Plant Simulation software. Specifically, the management system includes a data management software written in ASP.NET MVC with an SQLite database management system and uses the Simtalk programming language integrated within Technomatix Plant Simulation to store and update data.

1. INTRODUCTION

In production system management, the application of information technology plays a crucial role in managing and optimizing the operations of production clusters. Firstly, it allows for the adjustment of machine cluster data from the control room without the need to physically visit the machines for adjustments [1]. Instead of spending time and effort manually and periodically adjusting each machine, this system enables managers to make remote adjustments quickly and accurately. Managers can monitor, implement changes, and adjust machine parameters based on real-time data without needing direct access to the machinery [2-3]. Consequently, businesses can utilize management software based on data collected from machinery to monitor and adjust the production process accurately and efficiently [4].

By connecting machinery in the production system with automated information systems, data on operational performance, machine status, and technical specifications are automatically collected and sent to the management system [5-7]. Consequently, managers can analyze this data to gain a better understanding of machine operations, identify potential issues, and implement timely corrective measures [8].

Additionally, the production management software provides tools for production planning, managing inventory of raw materials and finished products, and automating production processes [9-10]. Through this automation, businesses can optimize the efficiency of the production system, reduce costs, and quickly adapt to fluctuations in market demand [11-12].

In summary, the application of information technology in production system management not only improves efficiency and labor productivity but also generates significant cost and competitive advantages for manufacturing businesses.

2. Research methodology

2.1 Simulation of the assembly line using Tecnomatix Plant Simulation

The model comprises machines such as the melting machine, injection molding machine, cooling conveyor, inspection station 1, surface processing machine, inspection station 2, painting machine, inspection station 3, Packaging Machine, waste product machine 1, waste product machine 2, and waste product machine 3.

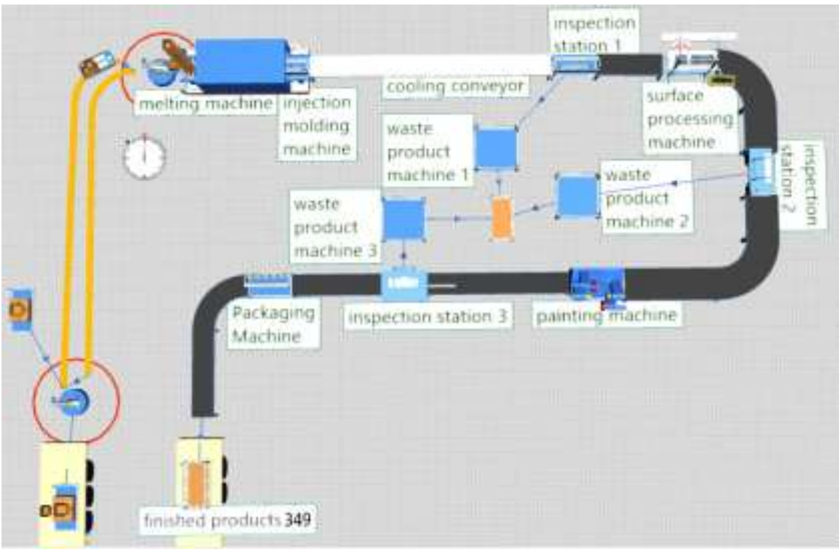

Figure 1: Simulation of the automotive plastic component assembly line using Tecnomatix Plant Simulation

Description of the model:

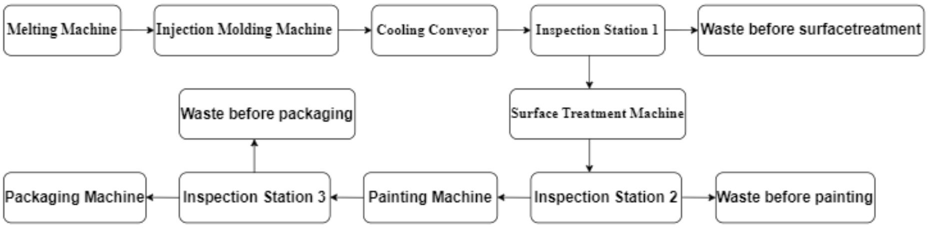

Figure 2: Automotive Plastic Component Production Line Model

Station 1: Melting Machine

Raw materials are fed into the melting machine to melt to the required temperature, preparing for the shaping process.

Station 2: Injection Molding Machine

Molten material is transferred to the injection molding machine. Here, the material is injected into molds to shape the product as required.

Station 3: Cooling Conveyor

The product is transferred from the injection molding machine to the cooling conveyor to stabilize and solidify its structure.

Station 4: Inspection Station 1

After cooling, the product undergoes a quality inspection to detect any defects or imperfections that may have occurred during the cooling process.

Station 5: Scrap Machine 1

Products that do not meet the quality standards from Inspection Station 1 are directed to Scrap Machine 1 for processing or recycling.

Station 6: Surface Treatment Machine

Products that pass the initial inspection are sent to the surface treatment machine to enhance quality, increase durability, or create aesthetic effects.

Station 7: Inspection Station 2

After surface treatment, the products undergo a second inspection to ensure there are no defects or damages.

Station 8: Scrap Machine 2

Products found defective at Inspection Station 2 are sent to Scrap Machine 2 for processing or recycling.

Station 9: Painting Machine

Products that pass the second inspection are transferred to the painting machine, where they are coated with a protective or decorative layer of paint.

Station 10: Inspection Station 3

Following painting, the products undergo a third inspection to ensure the paint quality and overall product standards are met.

Station 11: Scrap Machine 3

Products failing to meet the requirements at Inspection Station 3 are directed to Scrap Machine 3 for processing or recycling.

Station 12: Packaging Machine

The finished products are packaged and prepared for transportation to the final destination or storage.

2.2 Theoretical Calculation Model:

2.2.1 Applying Lean Six Sigma to Improve Production Line Efficiency

The paper proposes using the Lean methodology to implement changes to the processes, production techniques, and ultimately to evaluate the results. This should be measured by reductions in cycle time, inventory levels, etc. Furthermore, the team must develop a change plan outlining the necessary actions to implement the proposed modifications.

The team investigates the current value stream map of the aluminum profile production system. Information collected for each production step was used to construct the current state map. The current state map describes each step of the process, from receiving customer orders to shipping the final product. The parameters in the current value stream map are calculated using the following formulas:

$$AOP = APT - CO \quad (1)$$

Where:

AOP – Actual Operating Time

APT – Daily Production Time

CO – Daily Changeover TimeUT = AOP/APT ×100(%) (2)

Where:

UT – Utilization Rate of Each Station

PT – Takt Time

TT – Production Tempo

$$TCT = \sum_{(i=1)}^{n} x 〖TCT\_i 〗 \quad (3)$$

Where:

TCT – Total Value-Adding Time of the Production Process

$$TCT = \sum_{(i=1)}^{n} x 〖TCT\_i 〗 \quad (4)$$

Where:

TLT – Total Estimated Lead Time

CT – Machine Cycle Time

Based on the current value stream map, the paper aims to enhance the operational efficiency of the production line by researching and proposing changes to the production line and the takt time.

2.3 Theoretical Framework of Information Technology Management System

2.3.1 ASP.NET MVC and SQLite Database Management System

ASP.NET MVC:

ASP.NET MVC (Model-View-Controller) is a web application development framework developed by Microsoft, focusing on separating the application's logic into three main components: Model, View, and Controller:

Model: Represents the data and associated processing logic. In this project, the Model may include objects such as Products, Orders, Customers, etc. Data processing logic, such as adding, editing, deleting, and querying data, is implemented within Model classes.

View: Displays data to users. In our project, the View may include user interfaces for managing products, orders, and other features related to managing automotive plastic component production.

Controller: Responsible for controlling the application's workflow and interacting with both Model and View. In this project, the Controller handles user requests, calls logic processing methods from the Model, and passes corresponding data to the View.

SQLite Database Management System:

The SQLite Database Management System was selected for the project to ensure lightweight, portable, and easy deployment. SQLite is a lightweight, serverless relational database, suitable for small to medium-sized applications. Integrating SQLite into the project simplifies the development, deployment, and maintenance processes of the system.

2.3.2 Programming Language SimTalk

SimTalk is a programming language specifically designed for the simulation and modeling of manufacturing systems and industrial processes. Developed by Siemens PLM Software, SimTalk provides a flexible and powerful approach to simulating production processes and controlling automated systems.

Using the SimTalk programming language offers several benefits. Firstly, SimTalk provides robust features for simulating complex production processes, from machining to assembly. Secondly, SimTalk allows for the simulation of performance and optimization of production processes before actual implementation, saving time and costs.

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2.3.3 Interaction Between SimTalk Programming Language and ASP.NET MVC

In the interaction between the SimTalk programming language and ASP.NET MVC, the REST API plays a crucial role as a bridge between the two systems. REST API (Representational State Transfer Application Programming Interface) is an architectural style that allows applications to communicate with each other over the HTTP protocol in a simple and flexible manner. It is one of the most popular methods for creating web services, enabling access to and interaction with application data and functionalities remotely.

In the interaction model between SimTalk and ASP.NET MVC, the REST API is used to transfer data between these two systems. For example, when a SimTalk application needs to access data from a database managed by an ASP.NET MVC application, the REST API can be used to send HTTP requests from SimTalk to the ASP.NET MVC application and receive data in formats such as JSON or XML.

Table 1 Case of parameters

			Data statistics				
Case	**Parameter**	**Melting Machine**	**Injection Molding Machine**	**Cooling Conveyor**	**Surface Treatment Machine**	**Painting Machine**	
1	Processing Time (product per seconds)	130	22	11	22	105	[illegible]
	Maximum Capacity (product per seconds)	125	20	10	20	100	[illegible]
2	Processing Time (product per seconds)	175	31	15	30	145	[illegible]
	Maximum Capacity (product per seconds)	125	20	10	20	100	[illegible]
3	Processing Time (product per seconds)	240	42	22	39	190	

	Maximum Capacity (product per seconds)	125	20	10	20	100

Results and discussion

Results Table:

- Includes parameters: Number of processed products, number of defective products, total processing time, total waiting time. Details are as follows:
- Number of processed products: the number of products that have been packaged
- Number of defective products: the number of products detected with defects at each production or inspection station.
- Total processing time: the total time each station takes to complete the processing of all products that have passed through (tested over 24 hours).
- Waiting time: the amount of time a station has to wait before the next station completes its processing.

Machine name	**Melting Machine**	**Injection Molding Machine**	**Cooling Conveyor**	**Inspection Station 1**	**Surface Treatment Machine**	**Inspection Station 2**	**Painting Machine**	**Inspection Station 3**	**Packaging Machine**	**Overall Production Line**
Processing time (seconds per product)	130	22	11	11	22	12	105	12	40	130
Number of processed products (pieces)	664	664	664	664	557	557	529	529	497	664
Number of defective products (pieces)				107		28		32		167
Total processing time (seconds)	86320	86320	86320	86320	72410	72410	68770	68640	64480	86320
Waiting time (seconds)	0	71604	78897	78354,94	73936	79388	30620	79606	65905,96	79606

Table 2 Case 1

Total processed products: 664 pieces

Total defective products: 167 pieces

Comment:

- Production efficiency:
    - The overall process defect rate is 25.2%

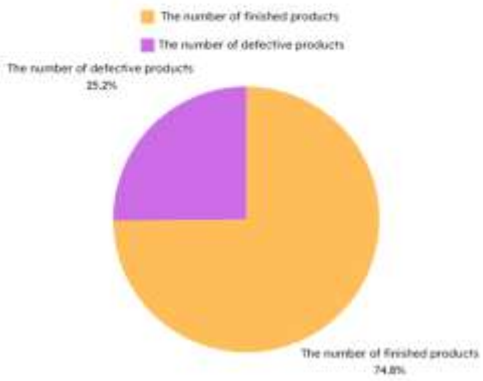

Figure 3: Chart illustrating the percentage of defective products in Case 1

- The machines with defective products include:
  - Inspection machine 1 has 107 defective products.
  - Surface treatment machine has 28 defective products.
  - Painting machine has 32 defective products.

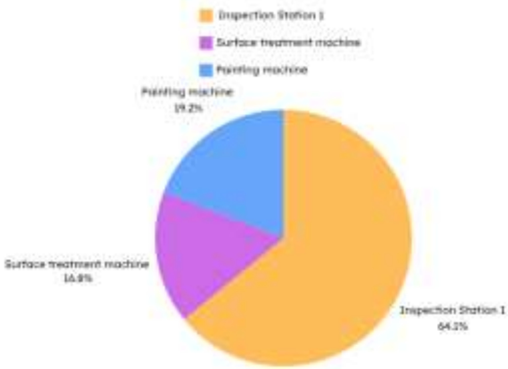

Figure 4: Chart depicting the percentage of defective products in Case 1

With a high defect rate, it's necessary to halt the production line and reduce the capacity of the machines. Based on the data from the software, identify which inspection station has the most defective products and prioritize troubleshooting at that station first.

Machine name	**Melting Machine**	**Injection Molding Machine**	**Cooling Conveyor**	**Inspection Station 1**	**Surface Treatment Machine**	**Inspection Station 2**	**Painting Machine**	**Inspection Station 3**	**Packaging Machine**	**Overall Production Line**
Processing time (seconds per product)	175	31	15	15	30	15	145	15	50	175
Number of processed products (pieces)	493	493	493	493	453	453	440	440	427	493
Number of defective products (pieces)				40		13		13		66
Total processing time (seconds)	86275	86275	86493275	86275	79275	79275	76825	76825	74375	86275
Waiting time (seconds)	0	70848	78720	78587	72540	79320	22415	79355	64675	79355

Table 3 Case 2

Total processed products: 493 sản phẩm

Total defective products: 66 sản phẩm

Comment:

- Production efficiency:

  - The overall process defect rate is 13,4%

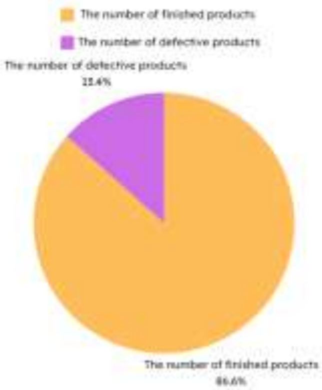

Figure 5: Chart depicting the percentage of defective products in Case 2

- The machines with defective products include:

  - Inspection machine 1 has 40 defective products.
  - Surface treatment machine has 13 defective products.
  - Painting machine has 13 defective products.

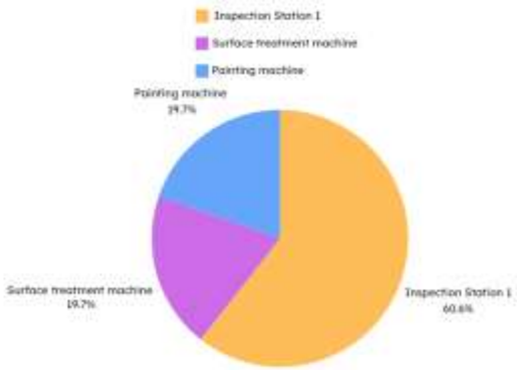

Figure 6: Chart illustrating the percentage of defective products in Case 2

The defect rates of the surface treatment machine and the painting machine are acceptable. However, the defect rate at the cooling machine is still high and needs improvement.

Machine name	**Melting Machine**	**Injection Molding Machine**	**Cooling Conveyor**	**Inspection Station 1**	**Surface Treatment Machine**	**Inspection Station 2**	**Painting Machine**	**Inspection Station 3**	**Packaging Machine**	**Overall Production Line**
Processing time (seconds per product)	240	42	22	20	39	20	190	20	70	240
Number of processed products (pieces)	360	360	360	360	349	349	345	345	341	360

Number of defective products (pieces)				11		4		4		19
Total processing time (seconds)	86400	86400	86400	86400	83520	83520	82320	82320	81360	86400
Waiting time (seconds)	0	71082	78262	78457	72588	78980	20750	78840	62020	78980

Table 4 Case 3

Total processed products: 360 pieces

Total defective products: 19 pieces

Comment:

- Production efficiency:
    - The overall process defect rate is 5.3%.

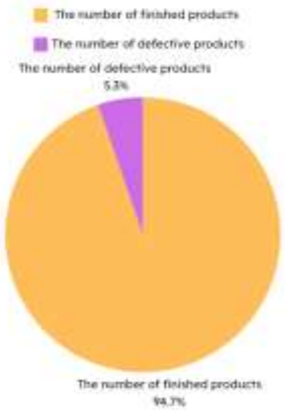

Figure 7: Chart illustrating the percentage of defective products in Case 3

- The machines with defective products include:
    - Inspection machine 1 has 11 defective products.
    - Surface treatment machine has 4 defective products.
    - Painting machine has 4 defective products.

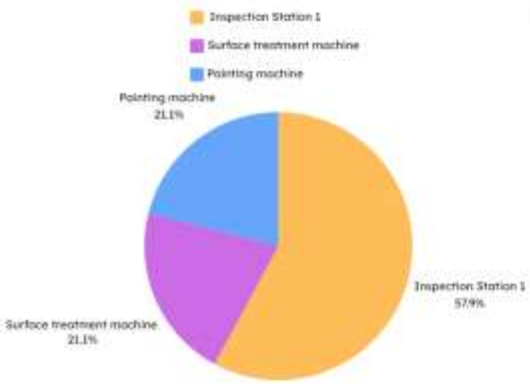

Figure 8: Chart illustrating the percentage of defective products in Case 3

The defect rate is within an acceptable range, allowing the production line to continue operating.

From the three cases above, we can draw the following conclusions regarding the production efficiency of the assembly line:

- In the case of high machine capacity (Case 1), the defect rate is high at 25%, significantly affecting product quality. Despite the small delay time, the output is low, and the production line needs to be stopped to address issues, especially at the machines: molding machine, cooling machine.
- In the case of medium machine capacity (Case 2), the defect rate decreases to an acceptable level of 13.38%. The delay time and the number of products produced are reasonable; however, there is still a need to improve the defect rate of the following machines: molding machine, cooling machine..
- In the case of low machine capacity (Case 3), the defect rate significantly decreases to 5.27%, with minimal delay time and fewer products produced. However, the defect rate is within an acceptable range, allowing the production line to continue operating.
- Overall, the case of medium machine capacity is the most optimal, achieving a balance between defect rate, delay time, and the number of produced items.

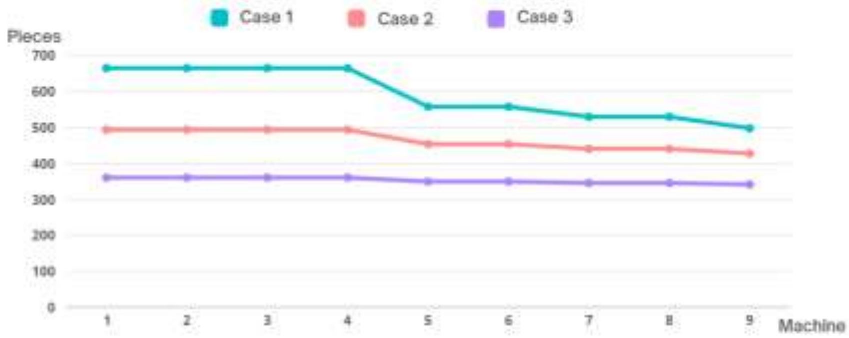

Figure 9: Chart of the number of products for the 3 cases

The chart on the number of processed products shows the quantity of products completed at each stage of the production process. This may include the total number of output products or the number of products passing through various quality control steps.

Early stages (Molding Machine, Plastic Injection Molding Machine): If the chart indicates a low number of processed products, it may indicate issues with the melting or molding speed. The production rate, machinery productivity, or raw material supply may need to be checked.

Middle stages (Cooling Conveyor, Inspection Station 1, Surface Treatment Machine): If there is a significant decrease in the number of processed products at this stage, it may be due to factors such as excessively long cooling time or many products being rejected at Inspection Station 1. The cooling process and the effectiveness of surface treatment need to be considered.

Late stages (Painting Machine, Inspection Station 3, Packaging Machine): If the chart shows a decline in the number of processed products at the end of the process, it may be related to painting time or the packaging process. The painting technique and the efficiency of the packaging process need to be checked to ensure smooth production flow.

In summary:

Production Capacity: The chart illustrating the number of processed products helps determine the production capacity of the assembly line. If the chart shows stability or continuous growth, it is a positive sign for production capacity.

Process Bottlenecks: Stages with a decrease in the number of processed products may indicate bottlenecks or areas that need improvement. Focusing on these areas can increase productivity and efficiency.

Time Management: Long waiting times between stages can lead to an overall slowdown in production speed. The chart can help identify stages that need optimization to minimize waiting time.

Thus, by using the chart illustrating the number of processed products, you can identify important factors in the production process and pinpoint areas for improvement to enhance efficiency and productivity.

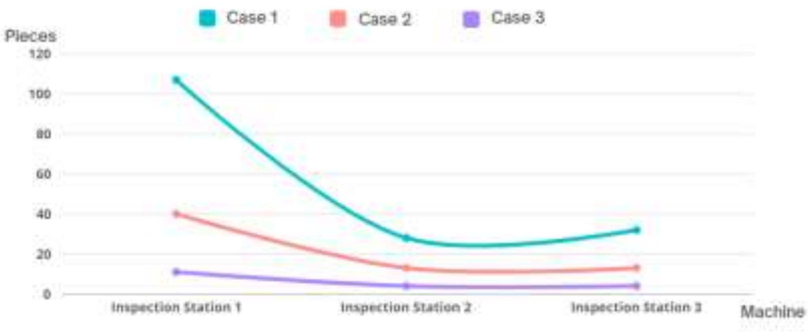

Figure 10: Chart illustrating the number of defective products in three cases

The chart illustrating the number of processed products before and after machine repairs shows the quantity of defective products at each stage of the production process. It can help identify bottlenecks in the assembly line or stages with high defect rates. This could be due to material quality issues, technical issues, or process errors.

Initial Stage (Heating Machine, Plastic Molding Machine): If the chart indicates a high rate of defective products at these stages, it may signal issues with the materials or machinery. Parameters such as heating temperature, molding pressure, or other machinery-related factors may need to be checked.

Intermediate Stage (Cooling Conveyor, Inspection Station 1, Surface Processing Machine): If the number of defective products increases at this stage, it could indicate problems with the cooling or quality inspection process. The inspection and cooling processes need to be re-evaluated to ensure there are no issues with machinery or operations.

Final Stage (Painting Machine, Inspection Station 3, Packaging Machine): If the chart shows a sudden increase in the number of defective products at the end of the process, it may be related to the painting or packaging process. The painting technique, paint quality, or packaging process should be examined to identify the root cause.

In summary:

Areas for Improvement: The chart can clearly highlight areas in the production line that need improvement. Points with high numbers of defective products indicate areas where focus is needed on quality control, machine maintenance, or employee training.

Overall Efficiency: If the chart shows a gradual increase in the number of defective products at each stage, it may indicate issues in the production process leading to error accumulation. Understanding the root cause is necessary to improve the process.

Production Costs: High numbers of defective products can increase production costs due to recycling or disposal. This can affect profitability and overall efficiency of the business. The chart illustrating the number of defective products is an important tool for evaluating and improving the production process. Through careful analysis, you can identify weaknesses in the process and implement appropriate corrective measures.

4. Conclusion

In this study, we presented a method of information management using information technology in manufacturing to optimize processes and enhance the efficiency of industrial machinery systems. Results from the research cases demonstrate that applying information technology to production management brings significant improvements in efficiency, cost reduction, and error reduction.

Specifically, integrating sensors and data management software allows real-time monitoring of the production process, thereby facilitating the rapid detection and resolution of technical issues. Additionally, information technology-based production management systems provide automation capabilities and efficient planning, leading to reduced waiting times and enhanced flexibility in production management.

Specific research cases have shown a significant decrease in error rates when applying information technology to production management. With the examination of three test cases, we can observe the productivity and quality of the production line's output. This demonstrates that using information technology in production management not only increases efficiency but also significantly contributes to improving product quality.

In the future, this research could be expanded by applying information technology to other manufacturing processes to evaluate the effectiveness of the proposed method in different contexts. Additionally, there is a need for further research on how to use advanced data analysis tools to predict and prevent technical issues before they occur. Therefore, it can be concluded that managing information with information technology in manufacturing is not only an effective method for optimizing processes but also a crucial strategy in improving performance and competitiveness in the industrial market.

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