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Design and Implementation of an RFID System for Order Tracking in Smart Manufacturing: A Case Study of a Mechanical Factory

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Abstract— Six Sigma is a well-liked technique for raising productivity and quality of output in industrial processes and process improvement initiatives. In the Six Sigma methodology, abnormalities in the operational process are reviewed and examined using the Define, Measure, Analyze, Improve, and Control (DMAIC) cycle. Corrective action is then taken to reduce bottlenecks to enhance productivity, ensure stable product quality, and create a tightly connected production cycle. This study proposes the use of integrating statistical hypotheses into the DMAIC cycle of the Six Sigma method and proposes the use of Enterprise Resource Planning (ERP) modules to monitor production processes at a major mechanical processing company. Lean tools are also suggested by the author to be used in the analysis phase. The research results show a reduction in the rate of late product delivery to users from 6.28% to 0.02% per month. The lean tool application model, statistical hypotheses, and industry 4.0 system are integrated into the EPR system at the company's improvement department and are considered a model for manufacturing companies to refer to in implementing improvements for their products. Production processes in different companies.
Keywords— Six Sigma, DMAIC, SPC, ERP, Smart Factory

Introduction

Today, Industry 4.0 technology is developing rapidly and is accompanied by fast-changing electronic devices designed according to Internet of Things (IoT) technology. IoT devices transmit data to each other through the radio system. The production process at mechanical component manufacturing companies uses a variety of processing equipment, but the connection between machines is not seamless and creates bottlenecks in information transmission between production processes together [1]. The quality of the production process is improved while the quality of the product is also improved, so the quality of the information in each production process is transmitted to each other and improves production quality, improving product quality [2]. In today's context, many manufacturers focus on implementing technical technology to automate production processes, and industry 4.0 technology is always of concern and priority for development by decision-makers in the company. However, the cost of implementing Industry 4.0 systems is still high and is also a big challenge for manufacturing companies [3]. Improving the reporting information system and communication system between production processes is always a top priority [4]. The daily reporting process at the mechanical company's production process is modeled according to the diagram in Figure 1.

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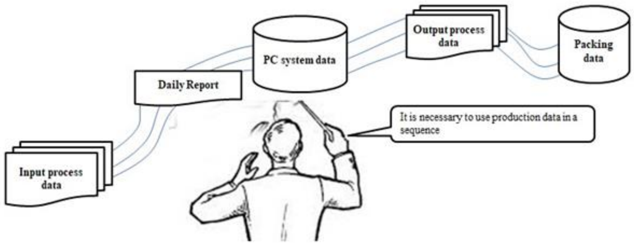

Figure I: Flowchart Of Daily Reporting

Customers today always demand high product quality and delivery time. The manufacturing process of mechanical products always requires complex techniques and has many manufacturing conditions. Monitoring and ensuring product completion time according to customer requirements is always a challenge [5]. Difficult calculations and product quality must always meet customer requirements. Each production process is installed with a daily report monitoring system, but it only stops at Industry 3.0 technology, so the interruption of data connection between production processes means production management staff still have to do manually when collecting product production data information at each stage, therefore, the collected results are incorrect and not the same as the actual product processing results at the production line [6]. Production data at each production process is always considered the top data for order managers to check processed products on the line, data on the production process, and data in other departments outside the production process. The production process also needs to be closely connected. A general control system for all production conditions during the production process such as an ERP system is necessary [7]. Figure 2 is a simulation of a common data connection information system that all manufacturing and business companies always aim to implement.

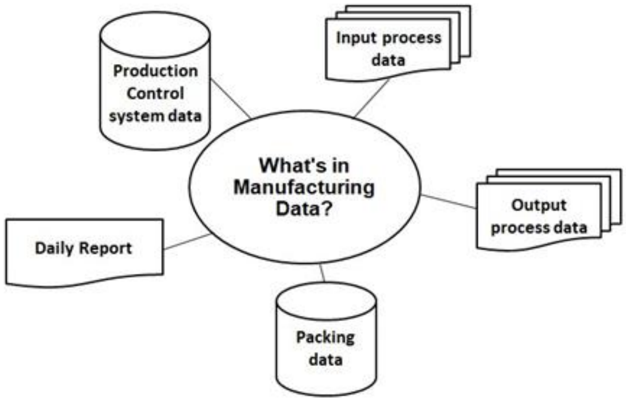

Figure II: Diagram Of ERP System

The ERP system is implemented through a data collection system using data collection devices using Industry 4.0 technology such as sensors, barcodes, or RFID devices. The data of each order that needs to be produced is encoded with barcodes. The barcodes record order information such as the customer's order number, the company's order number that needs to be processed, Processing date, processing time, and related information. The order tracking system is set up at the production stage [8]. However, it only stops at information collection activities and does not link between the actual quality of products on the line the number of processed products that pass or fail, and whether the data on the processing system is correct. produced in quantities that cannot be done with processed products [9]. ERP systems aim to solve that production processes at processing factories always aim to use industry 4.0 technology to solve the problem of clogging data flows between production processes. Real-time measurement systems are always considered a top development priority. This measurement system will be developed to check and measure product quality, control actual quantity based on quality, measure product quality, and control processing quantity on each order on the system [10]. Production planners can easily control product output

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without having to go down to the factory floor to count each product. The ERP system helps significantly reduce late shipments to customers and improve customer satisfaction [11].

This research paper proposes to deploy an RFID system to track production order information in the production process and use an automatic measurement system connected to the RFID system to track and combine quality information. products at each production process and quality at each corresponding production process. The system integrates the actual measurement value of product quality into the order output control system. The measurement system detects defective products, removes them, and at the same time performs a quantity subtraction on the ERP system, and order control staff can easily control the specific quantity of goods. Products that do not meet the requirements are rejected and the quantity is deducted directly from the order information at the corresponding processing line.

The research article is organized into the following specific sections: Section 2 offers an overview of the literature on relations research; Section 3 provides background information on the theoretical underpinnings of Lean Six Sigma, including the DMAIC cycle, hypothesis testing, and a methodology used in the case study. Section 4 presents the results of the research. Section 5 presents the findings regarding the research issue and future directions for mechanical plants.

Theoretical basis

The DMAIC tool is a key tool of the Six Sigma methodology, which helps continuous improvement activities within the company function well and control variation in the production process seamlessly [12]. Continuously controlling fluctuations in the production process is always a top concern, and data collection tools using RFID are always effective devices. The system uses Industry 4.0 techniques by using RFID to meet low-cost requirements in implementing Industry 4.0 systems [13]. However, the implementation system needs to consider and evaluate the benefits and disadvantages specifically when deploying an RFID system in a smart factory. The RFID system helps collect data at each production process and the Industry 4.0 system helps link data between production processes together [14].

Enterprise Resource Planning (ERP).

ERP is considered a management software program that integrates the entire system information sources from different sources into the same common database management system to help improve efficiency in general data management of production management systems in manufacturing and trading companies [15]. ERP helps companies effectively manage their business activities in terms of controlling operating costs, costs related to advertising the company's products to the market, and other general costs of the company's business activities [16].

The ERP system helps connect the activities of production processes and departments within the company and helps improve efficiency in controlling the activities of departments and production processes quickly and simply [17]. All data from departments or processes is connected to one data management facility, helping to save costs in controlling operations and avoiding errors and confusion when collecting data in operations [18]. ERP helps improve business efficiency, sales, and profits (Fig. 3).

Figure III: Flowchart Of ERP System.

The ERP system helps production management staff control all product information on each production process from a common database system (SQL system). All production management data is integrated into RFID, and from the production process, RFID scanning is performed, and all data in that order is transmitted to and saved in the database system [19]. However, the production management staff cannot confirm whether the product produced at each respective production process matches the data scanned from the RFID system. This problem means that the staff of production management may not be able to meet customer requirements by promising delivery dates, but actual delivery dates are not yet available because the number of orders and the actual

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quantity in the production process are not available [20]. This problem causes delays and makes customers unhappy.

Radio Frequency Identification (RFID).

The RFID system is designed as a data collection tool [21]. This tool helps activities in each production process be collected and transmitted to the database system, and the results serve operations collection, monitoring, statistical analysis, and overall monitoring (Fig. 4). In the product manufacturing supply chain, RFID helps collect and transmit information linking production processes. This collected data is collected continuously and in real-time at all production processes [22]. The corresponding output helps create big data in production and business activities. This data helps decision-makers within the company analyze and make future business decisions for the company [23].

Figure IV: Flowchart Of RFID System

Integrate RFID tools into the ERP system in production operations management.

Each customer's order has different information, but the production process is one process and the order management system is one. At each production process, a single system is designed to scan RFID tools, and the data of each order at each production process after being scanned with RFID will be collected and transmitted to the common facility management system data [24] on the ERP system (Fig. 5). The data collected for each process is connected into one system, and the following production process can see and use the data of the previous process and the following production process using the production conditions of the pre-production process to operate for nine processes. If the inspection finds that the previous process does not meet production completion, the following process will stop operating and issue a warning to the company's general system [25]. This operation helps The entire company and decision-makers can easily notice abnormalities and handle them.

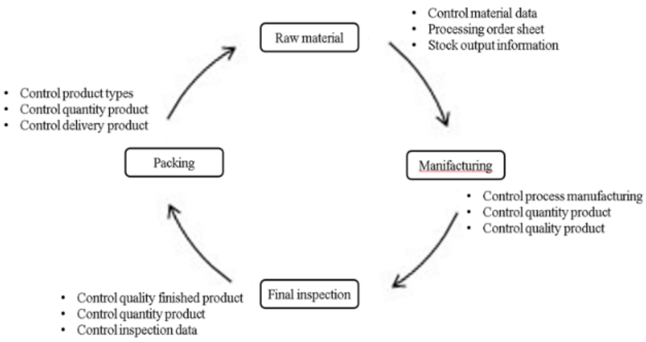

Figure V: Flowchart Of RFID And ERP Integrated System

Literature review.

A single production system is a manufacturing method where products are manufactured based on each customer's specific requirements. Single-production systems often use flexible technologies and processes to achieve high customization [26]. Through the use of technologies such as 3D printers, CNC (computer numerical control) machines, and automation systems, products can be manufactured flexibly and efficiently [27]. Some applications of single manufacturing systems include personalized clothing manufacturing, custom medical product manufacturing, electronics manufacturing, and auto parts manufacturing. However, it can also require more complex design and manufacturing processes than traditional mass production and can take more time and resources [28].

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Although the single production system has many advantages, there are also some disadvantages compared to traditional mass production methods. Below are some common disadvantages of single-production systems: High cost, long production time, and limited production capacity. Due to the customization of each product, quality risks may occur [29]. The complex manufacturing process and high technical requirements can lead to problems or errors in the product. Order management is complex because, with each order, the management, tracking, and operations process becomes more complex. This requires effective information and commodity management systems to ensure accurate and timely interaction between different departments in the production process. While this drawback exists, the single production system still has many advantages and can be successfully applied in highly customized industries such as fashion, medicine, and luxury products [30].

A step-linked production system is a production method in which production steps are linked and organized in a continuous flow. In a step-linked production system, production steps are arranged in a logical sequence. The following stage will receive the product from the previous stage to perform the next job, and this process is repeated until the product is completed [31]. The stages can be steps in the processing, assembly, quality control, and packaging processes. Some advantages of the integrated production system include increased efficiency, reduced waste, increased flexibility, and increased product quality. However, the process-linked production system also has some disadvantages. Implementing and maintaining this system can require a large initial investment and a thorough organizational and management plan. In addition, if one stage has a problem, it can affect the entire production process [32].

Some common disadvantages of this system are the risk of losing flexibility, failure propagation disorders, dependence on the slowest process speed, complex adjustment and maintenance, and difficulty in product distribution [33]. Despite this drawback, step-linked manufacturing systems are still widely adopted and offer many benefits, including optimizing the production process and increasing overall efficiency. However, implementing and managing this system requires careful consideration and detailed analysis to ensure it aligns with business requirements and goals [34].

RFID (Radio Frequency Identification) is a technology that uses radio waves to identify and automatically collect data about objects through RFID tags. Some ways to deploy RFID systems at a low cost include using low-cost RFID tags and taking advantage of existing infrastructure [35]. Choose low-cost RFID reading devices, use open-source software, deploy gradually, and scale according to need. Implementing a low-cost RFID system can have an impact on the system's capabilities and features. Therefore, it is necessary to carefully consider your requirements and goals before applying cost-reduction solutions [36].

RFID (Radio Frequency Identification) is an important technology in Industry 4.0 and can be used to perform step-by-step integration in the production process. Some ways that RFID can be applied to realize process alignment in the context of Industry 4.0 are product identification and tracking, automating process transitions, managing flexible production schedules, monitoring and managing quality, and optimizing production processes [37]. Using RFID to implement process linkage in Industry 4.0 helps increase flexibility, increase efficiency, and reduce errors in the production process.

RFID (Radio Frequency Identification) has many applications in implementing process linkage in the context of Industry 4.0: product identification and tracking, automatic process transfer, flexible production schedule management, quality monitoring and management, production process optimization, and inventory tracking and management [38].

When implementing RFID in process alignment, several challenges can arise: initial investment costs, standards and compatibility, reading distance, productivity, and performance, data management and security, and changing culture and processes [39]. To overcome these challenges, it is important to conduct a careful RFID implementation plan that ensures technical and economic

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feasibility and, at the same time, considers the cultural and process factors necessary to ensure success in implementing RFID in process alignment [40].

Methodology

Notation for Parameters.

X: Random variables of statistical calculations
W: Unacceptable domain of statistics
α: Significance level value of the statistic
z_0, t_{qs}, x_0^2: Statistical analysis calculations
s^2: Deviation area in statistics
μ, σ^2: Expected value of a statistical calculation
$\bar{X}$: Statistical difference estimate value
H_0: Null hypothesis
H_1: Test the change hypothesis
$t_{\alpha/2}^{n+m-2}$: The value is looked up from the student statistical distribution table
$x_{\alpha,n-1}^2$: Values are looked up from the standard statistical distribution table

Mathematical model of statistical hypothesis testing.

Definition 1: Use the statistical hypothesis z test using 2 calculation parameters, the mean value and the known variance value (Eq. 1).

$H_0: \mu = \mu_0, H_0: \mu \neq \mu_0$ (1)

Where: μ_0: constant.

The normal distribution in statistics is used to calculate sample mean values based on actual measured values. The efficiency of the implementation process is for $H_0: \mu = \mu_0$

$z_0 = \frac{\bar{X}-\mu_0}{\sigma/\sqrt{n}}$ (2)

The two regions of the unacceptable region of the z-test statistic are:

$W = \left(-\infty; -u\alpha_{/2}\right) \cup \left(u\alpha_{/2}; +\infty\right)$ (3)

The null region of the z-test statistic on the right is:

$W = (u_\alpha; +\infty)$ (4)

The z-test statistic is not acceptable in statistics:

$W = (-\infty; -u_\alpha)$ (5)

Definition 2: Perform an investigation of the normal variance by performing a variance test and checking the standard deviation value of the distributions σ^2 equal σ is authentic value. with σ_0^2: standard deviation with σ is σ_0. With $X_1, X_2, \dots X_n$ n observed values in the sample group area are randomly selected.

$H_0: \sigma^2 = \sigma_0^2, H_1: \sigma^2 \neq \sigma_0^2$ (6)

The results of checking the value of statistical calculations are:

$$x_0^2 = \frac{(n-1)S^2}{\sigma_0^2} \quad (7)$$

The two regions of the unacceptable region of the statistic are:

$W = \left(0; x_{1-\alpha,n-1}^2\right) \cup \left(x_{\frac{\alpha}{2},n-1}^2; +\infty\right)$ (8)

The null region of the statistic on the right is:

$W = \left(x_{\alpha,n-1}^2; +\infty\right)$ (9)

The null region of the statistic on the left is:

$W = \left(0; x_{1-\alpha,n-1}^2\right)$ (10)

DMAIC Methodology.

The mechanical product manufacturing process often includes the main steps from the design stage to the production and quality control stages. Specific processes may vary depending on the type of

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mechanical product and the size of the manufacturing plant [41]. The basic process steps are as follows: product design, raw material preparation, material processing, assembly, product finishing, quality checking, packaging, and shipping. Additionally, this process may vary depending on the specific requirements of each company and product (Fig. 6).

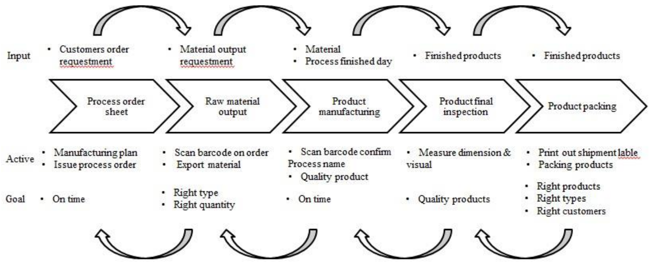

Figure VI: Flow Chart For Producing Mechanical Products.

The system for receiving orders from customers can be implemented using a SQL database (Structured Query Language). Below is an example of how to design an SQL database to receive and store orders from customers: Create an order table. Create a table in the database to store information about orders and goods from customers [42]. This table can include columns such as OrderID (order code), CustomerID (customer code), OrderDate (order date), and TotalAmount (total amount). Create order details table (OrderDetails): Create another table to store detailed information about each item in the order. This table can include columns such as OrderID, ProductID (product code), Quantity (quantity), and UnitPrice (unit price). Insert order data: When you receive an order from a customer, you can use INSERT INTO statements to insert data into the Orders and OrderDetails tables. Query orders: You can use SELECT statements to query and retrieve information about orders from the Orders and OrderDetails tables [43]. In reality, database processes and structures can be more complex, depending on the specific requirements of the business and the type of business.

If there is not a proper mechanism or link between order information and actual products in the system, it may cause a loss of link or synchronization between order data and product information. This can cause the following problems: Product information cannot be determined, Product quantity cannot be tracked, and total order value cannot be calculated. To solve this problem, in the order-receiving system, there needs to be a clear mechanism or link between order information and product information.

Define phase**:** *Apply the formula from formula 1 to the formula to calculate the order delay level of 2mm, the standard deviation of the delay is 6 orders per year. Perform a random evaluation of 100 samples of orders and find an average value of 6.4 orders at a significance level of 0.05. State the null hypothesis that the order will not be delayed:*

$H_0: \mu = 6.4, H_1: \mu \neq 6.4$

With, $\alpha = 0.05$, $u_{0.025} = 1.96$. Rejected position: $W = (-\infty; -1.96) \cup (1.96; +)$. Where $\bar{X} = 6.4$, $u_{qs} = \frac{(6.4-6.0)}{2*\sqrt{100}} = 2 \in W$. Rejecting H_0 , The delay rate arises, proving that in the production process there are inadequacies between order management information and the actual product produced or production management operations are still inadequate.

Analyze shipment data in the production process of a mechanical product line at a specific mechanical company over a period of time from January 2020 to June 2020 using analysis on Minitab 18.0 software . The analysis results show that the delay rate is 7.12% (Fig. 7).

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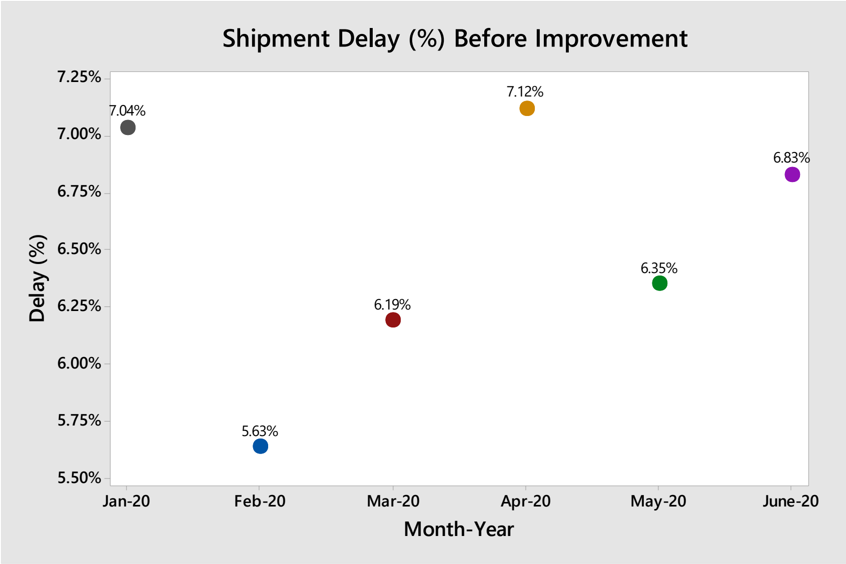

Figure VII. Analyzing Results Of Delay Products.

Many reasons can cause order delays during processing and delivery. The order processing system experiences technical problems or errors, which may lead to delays in recording, confirming, and forwarding orders. With a sudden influx of orders or an overload, processing, and delivery may not be fast enough to meet demand. The warehouse is not well managed and organized, so orders may be late. If there are shipping difficulties or problems during the transportation of goods, orders may be delayed. If the information in the order is incorrect or insufficient, the customer may need to be contacted again to verify or amend the information. Complicated issues related to orders. To minimize order delays, it is important to have a good order processing process, effective warehouse management, choose a reliable shipping partner, and ensure accurate and complete order information from the customer.

To solve the problem of losing order information and actual output in the production process. Apply barcodes or QR codes to each product or step in the production process. By scanning barcodes or QR codes, product information and production progress can be recorded and automatically updated in the system. This helps track and look up actual output information accurately and conveniently. Use the Internet of Things (IoT)-connected devices to automatically record production information and actual output. For example, sensors can be used to monitor production processes and measure product quantity and quality. Data from IoT devices is sent to the management system to update order information and the actual output. The traceback system allows the production process to be tracked back from the finished product to the corresponding raw materials and production stages. By recording detailed information about each step and the materials used, the actual output can be determined and linked to the corresponding order information. A production management system (Manufacturing Execution System, - MES) is an automated production management system that helps monitor and manage the production process from start to finish. It provides tools to record order information, track production progress, store actual output information, and automatically update data. MES helps ensure accuracy and synchronization between order information and actual output.

Measure phase: *Figure 8 analyzed the causes of order delay and showed that the cause was a defect that occurred on the line, but the SQL system could not control it and still recorded a different quantity compared to the actual processed product economics in the production process.*

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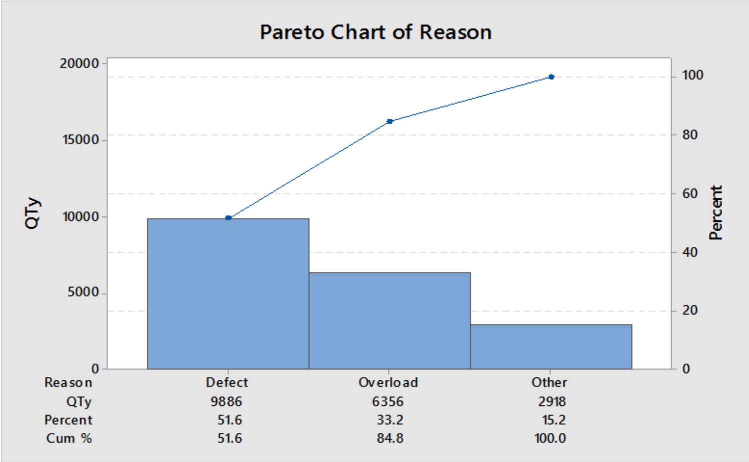

Figure VIII. Result Of Analysis For Delay Products

Apply the fishbone diagram (Fig. 9) to analyze possible causes of product delay in the production process. Shortages of materials needed for production can cause order delays. Failure to meet material demand or problems in material supply may be the cause. The production process is not carried out according to regulations; there are omissions or errors in the production steps. This can cause the product to fail or require repair and remanufacturing, leading to late orders. Machinery and equipment that is not working properly or has technical problems can slow down production and lead to late orders. Employees performing the production process may encounter errors in performing work, making mistakes, or not ensuring product quality, causing delays in orders. Ineffective management, inaccurate production scheduling, a lack of coordination between departments, or no clear management process can cause order delays. Peripheral factors such as bad weather, shipping problems, delays in the supply chain, or other uncontrollable factors can cause order delays.

QR code systems can be used in production and order management processes to track and manage product information. However, some possible causes of order delays related to the QR code system include: If the QR code system has technical problems such as code reading errors, incorrect format, or incompatibility with the QR code system, different code-reading devices, which can lead to order delays. Employees who are not fully trained on how to use the QR code system or do not clearly understand the process of scanning the code and entering information can cause errors and slow down the order processing process (Fig. 10). There is a problem with the network or data management system, which may affect the ability to access and record information from the QR code. The information stored in the QR code is inaccurate or missing, which can lead to the need to confirm, update, or modify information, causing order delays. The QR code scanning process is not optimized and can result in time-consuming or inefficient processing, which can cause order delays.

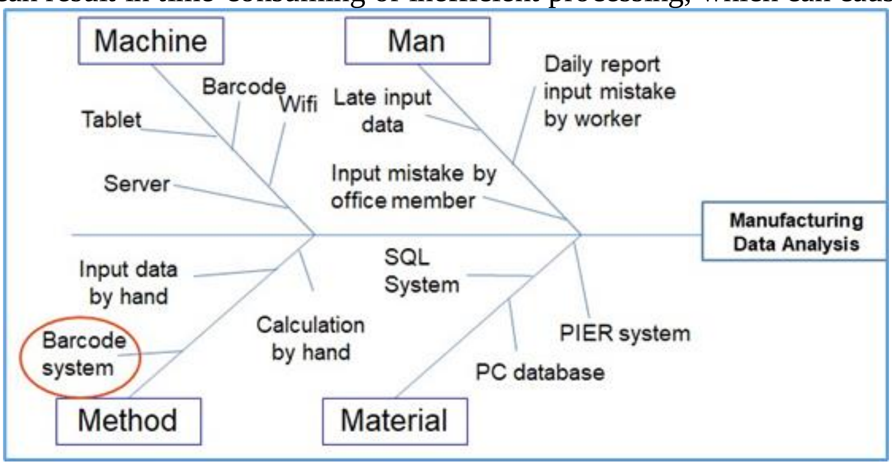

Figure IX: Root Cause Analysis By Fishbones Diagram

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Figure X: Scan RFID Code In Process

Analysis phase : *Below is a 5 Whys chart (Fig. 11) to analyze the cause of order delays in the production process due to problems related to the QR code system: Problem: Order delays arise in the production process related to the QR code system. Why are orders late? Why? Because the information from the QR code system is not recorded on time. Why is information not recorded on time? Why? Because the QR code system had technical problems. Why does the QR code system have technical problems? Why? Because the QR code system is not compatible with existing code-reading devices, why is the QR code system not compatible with existing code-reading devices? (Why?), Because there is no process to test and ensure compatibility before deploying the system. Why is there no process to test and ensure compatibility before deploying the system? (Why?) because the system implementation team did not have adequate testing and quality assurance procedures. Based on the above analysis, the root cause of the problem of late orders due to the QR code system is that there is no process to check and ensure compatibility before implementing the system. To solve this problem, it is necessary to establish a testing and quality assurance process for the QR code system before applying it to the production process.*

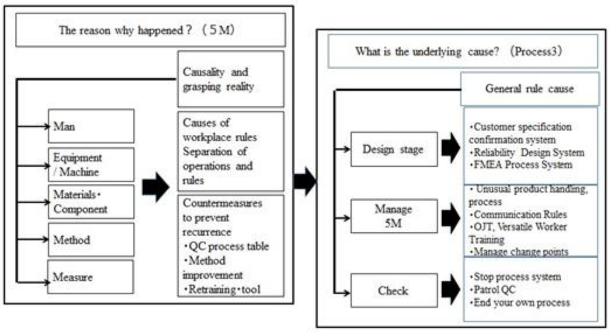

Figure XI: Flow Chart Of 5 Whys

A loss of link between QR code information and the actual product during the production process can cause order delays. During the production process, problems may occur when the product does not have a QR code attached, the QR code is incorrectly attached, or it is lost. QR Code codes may be damaged, blurred, or unreadable due to printing errors, stains, or damage to the code-reading device. At that time, staff must process the QR code or replace the code with a new one, resulting in a delay in the order. Data synchronization process between QR Code and information management system. Errors may occur in updating, storing, or transmitting data, leading to a loss of connection between the QR code and the actual product information. The QR code attached to the product may not be accurate or correspond to the actual information about the product. The product information associated with the QR Code is incomplete or inaccurate, which may cause order delays. To solve the problem of losing the link between QR code information and the actual product in the production process, it is necessary to establish quality inspection procedures and ensure the accuracy of QR code

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and product information. An online inspection system that incorporates actual QR information at each production step is needed.

Improve phase: *To design an RFID system integrated into an online measurement system incorporating IoT (Fig. 12), you can follow these steps: Determine system requirements, Based on system requirements, select suitable RFID technology. There are many types of RFID technology, such as very high frequency (UHF) RFID, mid-range frequency (HF) RFID, and low frequency (LF) RFID. Determine the right RFID technology to meet measurement requirements and connect to IoT systems. Identify the components needed for the system, including RFID devices, measurement devices, sensors, IoT gateways, and data processing systems. Design the network structure and how to connect components. Install and deploy RFID devices at the necessary locations in the measurement process. Be sure to place RFID tags or RFID devices on the product or material to be measured. Establish a connection between the RFID device and the IoT system through an IoT gateway. Data collected from RFID devices will be transmitted to the IoT system for processing and storage. Develop applications or user interfaces to display and manage data collected from RFID systems. This allows users to access and track measurement information, along with other features such as reporting, alerts, and management. Conduct testing of the IoT-integrated RFID system to ensure proper operation. Optimize system performance and reliability, and adjust parameters if necessary. Once testing is completed, deploy the IoT-integrated RFID system into the production environment. Ensure system maintenance and support to ensure stable and reliable operations.*

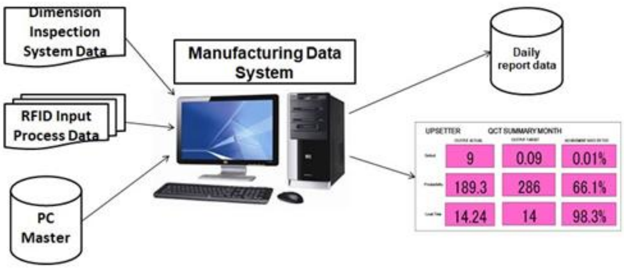

Figure XII: Diagram Of Integrate RFID To Erp Systems

The RFID code system for online control of factory orders is an effective solution to monitor and manage the production process (Fig. 13). Each product is assigned a unique RFID code. The RFID code contains product information such as batch number, production date, ingredients, and specifications. As products move through the production process, workers or machines scan RFID codes to record information and retrieve product-related data. Scanning can be done using a mobile device or a barcode scanner. Through the RFID code system, the production process can be tracked online. When products are scanned, data about the production process, such as the current location, time, production stage, and operator, can be updated in the system. This helps managers and employees know the production progress of each product and react promptly when necessary. The FIDR code system provides quality inspection and control during the production process. When scanning the RFID code, employees can access information related to product quality, such as test results, technical specifications, and material information. The RFID code system allows tracking of the history of each product; users can look up information about the origin, production process, shipping history, and other information related to the product.

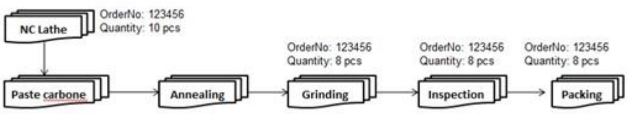

Figure XIII: Flow Chart Of RFID System Control Products In Process

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Control phase: *Visual management using a display system incorporating RFID during the production process is an effective method to monitor product information (Fig. 14). RFID is a technology that allows the remote identification and recording of information through radio waves. Each product is fitted with an RFID tag containing specific information about that product. Displays are installed at key locations in the production process. This screen is capable of displaying information from RFID tags. As products move through the production process, RFID devices read information from RFID tags attached to the product. This information may include batch number, date of manufacture, current location, and other information related to the manufacturing process. The displays are connected to the data management system and receive information from RFID devices. Product information is displayed directly on the corresponding screen. Thanks to that, employees and managers can track product information visually and easily. The RFID combination screen system allows real-time tracking of product information. As the product moves, the information is updated and displayed immediately on the corresponding screen. This helps managers and employees have an overview of the production process and can react promptly when necessary. Display systems that incorporate RFID in the manufacturing process bring many benefits, such as reducing errors, increasing accuracy and efficiency, providing intuitive product information, and helping to manage the production process effectively.*

Figure XIV: Actual Real-Time Visual Management Product Information

RFID (Radio Frequency Identification) product tracking method in the production process is an effective way to track and manage product information (Fig .15). Each product is fitted with an RFID tag containing a chip and an antenna. RFID tags can be attached directly to products, labels, or any location that can be easily scanned. As products move through the manufacturing process, RFID readers are placed at strategic locations to read information from RFID tags. These devices use radio waves to communicate with RFID tags and collect data from the chip in the tag. Data collected from RFID tags is transmitted over the network to a data management system. Through a network connection, data is transferred to a monitoring center or server system for processing and storage. The data management system will store information from RFID tags and provide tools for tracking and managing products. This information may include batch number, date of manufacture, current location, manufacturing process, and other related information. Data from RFID tags can be used for analysis and decision-making. For example, through RFID data analysis, you can determine production progress, locate products, find process problems, and optimize production operations. RFID

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product tracking in the production process brings many benefits, such as increased accuracy, increased efficiency, reduced errors, improved production processes, and data management.

Figure XV: Actual RFID System In Process

Result and discussion

Result.

Using RFID technology in product quality control systems at the production line can bring many important benefits. RFID allows accurate identification of product information, including ingredients, origin, lot number, specifications, and other quality control information. This helps ensure that products are inspected and quality controlled accurately, minimizing errors and mistakes. Real-time product tracking can track and monitor products throughout the production process. Through RFID reading devices, product information can be updated and recorded immediately. This allows quality control and management staff to have an overview of production progress and the ability to detect problems as soon as they occur. RFID provides product traceability throughout the entire production process. By attaching RFID tags to each product, you can track the travel schedule, processing process, and quality control steps that the product has gone through. This is useful in identifying the source, determining the cause of quality problems, and taking responsibility when problems occur. Enhance quality management and process compliance as RFID allows for the automation of recording quality information and process compliance. As products go through quality checks, data from RFID tags can be used to automatically confirm the inspection and store the test results accurately. This helps optimize quality control processes and ensure that all regulations are followed. When there is a request to check quality or look up product information, RFID helps speed up the process and reduce search time. Through scanning RFID tags, product-related information can be retrieved quickly and accurately, helping quality management and employees to react promptly and make necessary decisions. In summary, the use of RFID technology in the product quality control system at the production line brings many important benefits, such as high accuracy, real-time product tracking, enhanced traceability, strengthened quality management and process compliance, as well as increased ability to react and look up information. This contributes to improved production efficiency and quality while minimizing errors and mistakes during quality control. Figure 16 details the product delay results in

6 months of implementing production process improvements applying RFID to the product quality control process and the order delay results were reduced from 7.12% to 0.02%.

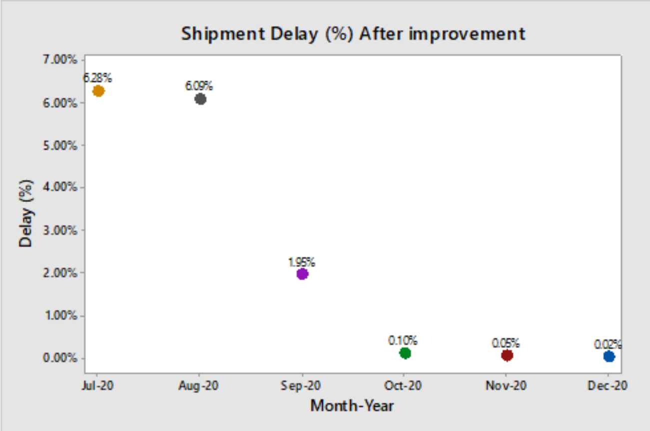

Figure XVI: Actual Result Of Delay Products

Perform re-validation by testing 20 sample orders, with $S'^2 = 0.0153$, The standard deviation in statistics is 0.01, significance level of 5%. Apply formulas from formula 6 to formula 8 and normal distribution to perform re-evaluation.
Null hypothesis: $H_0: \sigma^2 = 0.01$; $H_1: \sigma^2 > 0.01$. With, $\alpha = 0.05$, follow Chi-square distribution of degrees of freedom 19 and: $x^2_{0.05;19} = 30.144$. Reject domain: $W = (30.144; +\infty)$. With $s'^2 = 0.015(1^2)$, the value of the statistical: $x_{qs} = \frac{(19-1)\times 0.0153}{0.01} = 29.07 \notin W$. Accept hypothesis H_0. The analysis results show that the RFID system implemented in the production process is highly effective and meets the requirements.
Discussion.
There are several strengths of RFID systems in controlling product quality in the production process: RFID systems allow for automatically recording product information quickly and accurately. Reading information from RFID tags does not require direct contact, saving time and increasing efficiency in the quality control process. RFID allows for real-time tracking of a product, from the time it is produced to the time it is inspected for quality. This gives managers and quality control staff an overview of the production process and the ability to detect problems immediately, helping to minimize response times and ensure product quality. Enhanced product tracking and history allow tracking of product movement and processing in the manufacturing process. By attaching RFID tags to products, the origin and history of the product can be accurately determined. This is useful in determining the cause of quality problems and tracing products to their origins when necessary. RFID helps automate the recording of quality information and process compliance. As the product passes through the inspection steps, data from the RFID tag can be used to automatically confirm the inspection and store the results accurately. This helps optimize quality control processes and ensure that all regulations are followed. RFID helps reduce errors and mistakes in the quality control process. Information from RFID tags is converted automatically and does not require human intervention, minimizing the risk of confusion and increasing data accuracy. In summary, RFID systems for product quality control in the production process bring many strengths, such as automation and high performance, real-time tracking, enhanced traceability and product history, and optimization. streamline quality control processes and improve reliability and accuracy. This helps improve quality control processes, ensure product quality, and increase the ability to react quickly in the event of a problem being detected.
Although RFID systems have many advantages, there are also some disadvantages to consider: Implementing an RFID system can require large initial investments, including purchasing RFID readers and tags, and installing the infrastructure. layer, and integrating it into existing systems.

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This cost can be a barrier for small and medium-sized businesses. The reading distance of RFID devices can be limited, especially when using high-frequency RFID. Therefore, in some cases, direct or close contact is required to ensure the reading of information from the RFID tag. Environments with electromagnetic interference (EMI) or interactions with radio frequencies can cause malfunctions and reduce the performance of RFID systems. This may occur in some industrial environments or with multiple electronic devices operating at the same time. RFID technology collects and stores a variety of information about products and manufacturing processes. This raises issues about data management and protecting user privacy. Ensuring information security and compliance with privacy regulations is an important factor to consider when implementing an RFID system. For businesses with existing infrastructure and manufacturing processes, implementing an RFID system may require changes and adjustments. This can cause disruptions in workflow and require time and resources to adapt to new technology. Despite its disadvantages, RFID technology still brings many benefits in product quality control. However, before implementing the system, it is necessary to carefully consider the above factors and ensure that RFID technology is suitable for the specific needs and production environment.

Conclusions & recommendations

Applying RFID to product quality control at the production line can have many practical effects, including increased accuracy and reliability because information from RFID tags is read quickly and accurately. , minimizing errors caused by manual recording or using other methods. This improves the accuracy and reliability of the quality control process. RFID allows for automatically recording product quality information quickly and continuously. Reading data from RFID tags does not require direct contact and can occur in real-time. This helps speed up inspection and reduce quality control time throughout the entire production process. RFID helps automate the recording of quality information and compliance with control processes. Data from RFID tags can be used to automatically confirm testing and store results accurately. This optimizes quality control processes, reduces the need for manual checks, and ensures that all regulations are followed. RFID allows tracking the movement and processing of products in the production process. By attaching RFID tags to products, the origin and history of the product can be accurately determined. This is useful in determining the cause of quality problems and tracing products to their origins when necessary. RFID helps identify quality problems early in the production process. With real-time monitoring and automatic recording of information, managers and quality control staff can detect problems immediately and take timely corrective measures. This helps reduce errors and improve the final product quality. In summary, applying RFID to product quality control at the production line brings many practical effects, such as increasing accuracy and reliability, increasing inspection speed, optimizing quality control processes, product traceability, and quick response. The use of RFID helps improve product quality control processes and ensure that products meet established quality standards.

There are several potential future research directions for applying RFID to manufacturing processes. Here are some important research directions: Research could focus on developing more advanced RFID technologies to increase interactivity and automation in manufacturing processes. RFID can be integrated with other technologies, such as telecommunications systems, artificial intelligence (AI), blockchain, and big data, to create a more intelligent and reliable system. Research could focus on developing smart analytics and data management technologies to process and leverage data from RFID systems. This includes analyzing data to find trends, patterns, and important information about product quality, thereby improving production processes and making timely decisions. RFID can be used to enhance supply chain management and product traceability. Research may focus on developing methods and processes to track and determine the origin and movement of product components in the manufacturing process. This plays an important role in ensuring product quality and safety, as well as helping to manage risks and optimize processes.

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RFID poses security and data privacy challenges. Research may focus on developing security and privacy management solutions, including data encryption, authentication, and access authorization. This ensures that the information from the RFID tag is protected and can only be accessed and used by authorized people.

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