

ENHANCING ORDER FULFILLMENT
THROUGH PRODUCTION PROCESS REENGINEERING USING MANUFACTURING
EXECUTION SYSTEM AS A REFERENCE MODEL

by
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ABSTRACT

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Order Fulfillment is one of the vital indicators for enterprise operations, and its improvement is closely linked to process optimization and information integration. The ISA-95 standard provides a general standard for the interaction of information within enterprise control systems. Manufacturing Execution System (MES) is an information management system for the shop floor that enables the tracking and management of factory activities through the collection, integration, and analysis of data. MES provides real-time information of the workshop's status, including machine conditions, raw materials, production progress. This thesis utilizes MES as a reference model and draws from the ISA-95 standard, proposing a "Reengineering Production Process" aiming to improve the order fulfillment. In this thesis, a guide for reengineering the production process will be provided, and using a machining factory as a case study. By reengineering the processes within this company, the aim is to enhance its order fulfillment. Although this study did

not implement process reengineering in the case company in real yet. However, the proposed process reengineering plan was generally recognized by the case company.

Keywords: Manufacturing Execution System (MES), Manufacturing Operation Management (MOM), ISA-95 Standard, Order Fulfillment, Process Reengineering

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I. Introduction

1-1 Research Background

In recent years, we have frequently heard terms such as Industry 4.0, smart factory, smart manufacturing, and digital transformation. This not only reflects the rise of these concepts in the manufacturing industry, but also highlights their importance in today's fiercely competitive market.

Since Industry 4.0 was proposed in Germany in 2011, companies around the world have begun to actively explore and implement related technologies and strategies to adapt to this new industrial revolution. Industry 4.0, also known as smart manufacturing, brings a new manufacturing model to companies (Xu, Xu, and Li 2018).

Given the current trends of short product life cycles, expanding product varieties, and dynamic market changes, a smart factory should be able to address these challenges (Mantravadi et al. 2020). Manufacturers also look forward to manufacturing systems that can handle the market uncertainties (Mantravadi et al. 2022). One of the smart factory's goals is to grasp the complete view of manufacturing operations, and this goal needs the integrate data from several different sources to achieve it (Almada-Lobo 2016). MES is a production management tool that connects the enterprise planning level and shop floor level. MES collects data from the shop floor through Programmable Logic Controller (PLC), Supervisory Control and Data Acquisition (SCADA), and other smart devices. Also, MES can integrate the data from Enterprise Resource Planning (ERP) as well (Shojaeinasab et al. 2022). MES is considered to be one of the key technologies for

realizing smart factories (Mantravadi et al. 2020), which helps companies achieve the goals of Industry 4.0, improve production efficiency, and achieve higher competitive advantages.

Many companies are striving to align with the demands of future factories by investing in advanced enterprise software. Through the available data provided by these software to manage their production (Mantravadi and Møller 2019). MES is a popular software tool in the manufacturing industry (Mantravadi et al. 2020). However, the implementation of digital tools such as MES is not an easy task, especially for small and medium-sized enterprises (SMEs). Throughout the implementation process, various obstacles may encountered. According to Mittal et al. (2018), small and medium-sized enterprises (SMEs) have fewer financial resources, use advanced manufacturing techniques less frequently, and engage in fewer collaborations with academic institutions (universities) when compared to multinational enterprises (MNEs) (Mittal et al. 2018). Dutta et al. (2022) further suggests that due to a lack of expertise and financial resources, SMEs may hesitate in implementing MES. This illustrates that SMEs lag behind MNEs in financial and technological aspects, consequently trailing significantly in the implementation of Industry 4.0 (Dutta et al. 2022).

Order fulfillment process is the procedure that a company follows from the moment it receives an order until the product or service is handed over to the customer (Nanda and Patnaik 2023). Order fulfillment has a direct impact on various aspects of a company's operations and sales.

One primary focus of improving order fulfillment is on process improvement. Lin and Shaw (1998), Yu and Huang (2001), Dias et al. (2019), Maia et al (2019) and Nanda and Patnaik (2023) are among the scholars who have conducted research pertaining to the order fulfillment process. These studies discussed the significance of the order fulfillment process within various domains. Thus, improving the order fulfillment process is a crucial factor in addressing order fulfillment issues.

Identifying and rectifying problems within the process is very important for the advancement of enterprises (Stewart 2020). MES as a shop floor information system (Mantravadi et al. 2020), it can collect and management data from the production process (Chen and Voigt 2020). Thus, this study aims to integrate the concept of MES into the production process. The goal is to take MES as a reference to enhance the order fulfillment through the reengineering of production process. This study will conduct a case study within a Small and Medium-sized Enterprise (SME) mechanical processing plant, aiming to reengineer its production process to enhance the order fulfillment. Due to the limited professional manpower and financial resources of SMEs, this study aims to assist SMEs in enhancing their competitiveness by providing a way to reengineer the production process, instead of asking companies to purchase software that may cost tens of thousands dollars.

1-2 Research Purpose

The aim of this study is to enhance the order fulfillment by the production process reengineering. The production process reengineering will utilize MES as a reference to create a production process reference model, which will be used to reengineer processes in the metal manufacturing industry. Figure 1 illustrates the phased objectives of this study. The enhancement of order fulfillment will be achieved through production process reengineering, a method that involves the implementation of the reference model.

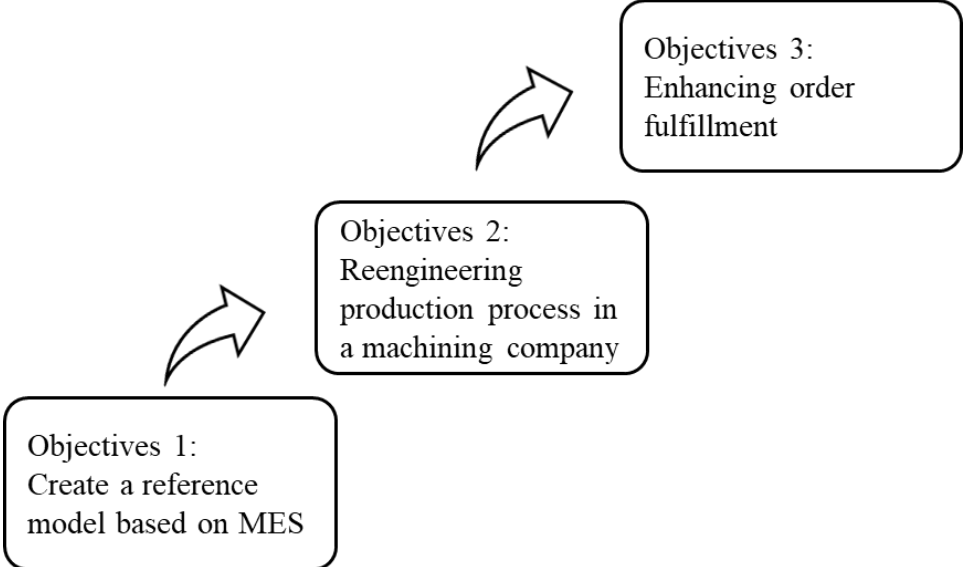


Figure 1 Three Phased Objectives

1-3 Research Outline

This research is organized as follows (refer to Figure 2):

Chapter I: The first chapter provides a concise overview of the research background, encompassing Industry 4.0 and the role of Manufacturing Execution Systems in facilitating the realization of the smart factory concept. It also discusses the rapid market changes and the challenges associated with implementing MES.

Chapter II: This chapter reviews the literature related to Manufacturing Execution System and order fulfillment. It discusses Manufacturing Enterprise Solutions Association (MESA)'s definitions and functionalities concerning MES, as well as discusses the relationship between Manufacturing Operation Management (MOM) and MES.

Chapter III: This chapter will address the research problem, methods. In this chapter, the guidelines for the reengineering production process and production process reference model will presented. This model is generated using MES functionalities and the information provided by ISA-95 (International Society of Automation) standard as a reference.

Chapter IV: This chapter utilizes one machining SME manufacturer as a case study example. It aims to provide a demonstration illustrating how a company can follow the guidelines for reengineering the production process.

Chapter V: This chapter will give the conclusion and future work.

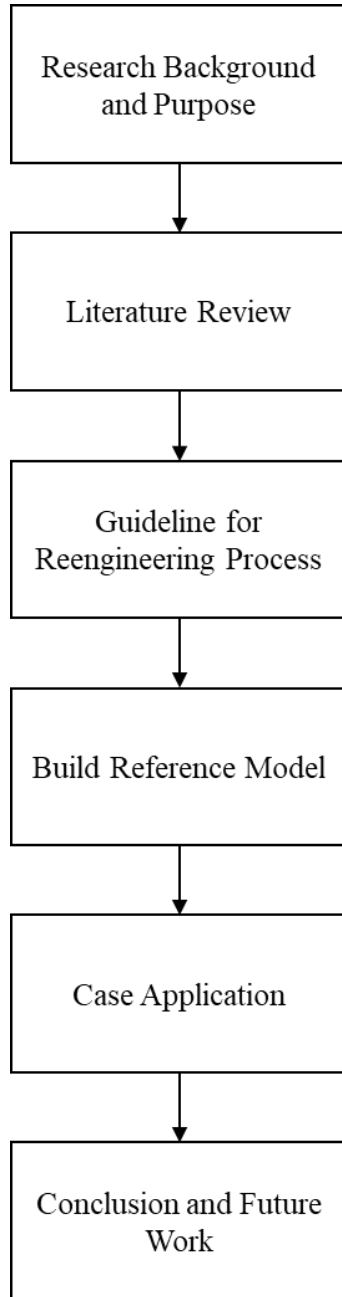


Figure 2 Research Flow Chart

II. Literature Review

2-1 Manufacturing Execution System (MES)

Manufacturing Execution System (MES) was initially used in the 1992 by AMR (Advanced Market Research, a industry and market analysis firm) (Chen and Voigt 2020). MES is an information management system for the shop floor that enables the tracking and management of workshop shop floor through the collection, integration, and analysis of data. MES provides real-time information of the workshop's status, including machine conditions, raw materials, production progress, etc. MES should be able to manage the top-down data flow (D'Antonio, Bedolla, and Chiabert 2017).

Manufacturing Enterprise Solutions Association(MESA International, former Manufacturing Execution System Association), established in 1992, is a trade association representing MES software developers and vendors. (MESA International 1997a). According to the MESA official website, MESA is a global nonprofit fostering education and collaboration in Smart Manufacturing and Industry 4.0 among manufacturers, industry leaders, and solution providers now.

MES is defined by MESA as "Ac system that deliver information enabling the optimization of production activities from order launch to finished goods. Using current and accurate real-time data, MES guides, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non-value added activities, drives effective plant operation and processes (MESA International 2000). "

Figure 3 is MES function model provided by MESA International in 1996. This model presents 11 main functions of MES and relationships with other functional areas. There are 11 MES functions defined by MESA: (1) Resource Allocation and Scheduling, (2) Operations/Detail Scheduling, (3) Dispatching Production Units, (4) Document Control, (5) Data Collection/Acquisition, (6) Labor Management, (7) Quality Management, (8) Process Management, (9) Maintenance Management, (10) Product Tracking and Genealogy, (11) Performance Analysis (MESA International 1997a).

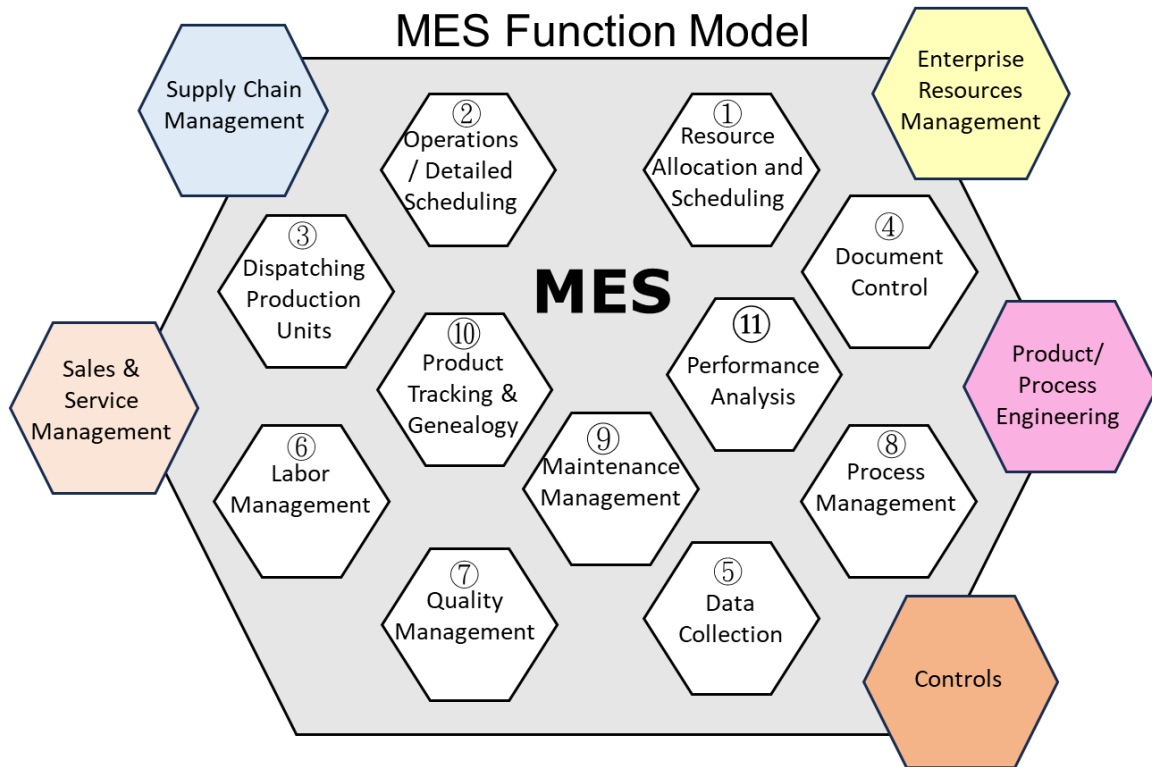


Figure 3 MES Function Model (MESA International 2023)

1. Resource Allocation and Scheduling: This function manages the resources including equipment, tools labor skills, materials, and other entities such as documents for work

instruction. This function can provide detailed resource history, ensures proper equipment setup, provides real-time status updates and involves reservation and dispatching to meet scheduling objectives.

2. **Operations / Detail Scheduling:** This function organizes sequencing based on priorities, attributes, or specific production unit characteristics to minimize setup. Recognizes alternative and overlapping operations for precise time or equipment loading adjustments.
3. **Dispatching Production Units:** This function manages the flow of production units in the form of jobs, orders, batches, lots, and work orders. Dispatch information is shown in the order they need to be done and updated as things happen in the factory. This function allows to change plans in real-time if something unexpected happens on the factory floor.
4. **Document Control:** This function manages records/forms essential for production units, including instructions, procedures, part programs, etc. and stores historical data.
5. **Data Collection/Acquisition:** This function collects production data, populating related forms and records manually or automatically in real-time.
6. **Labor Management:** This function provide the information of personnel status including time and attendance reporting, certification tracking. Labor Management can interact with resource allocation for optimal assignments.
7. **Quality Management:** This function performs real-time analysis of manufacturing

measurements to ensure product quality control and recommends corrective actions and manages inspection operations.

8. Process Management: This function monitors production and corrects process activities automatically or by providing support for operators to make decisions for correcting.
9. Maintenance Management: This function tracks and directs equipment/tool maintenance activities, schedules preventive maintenance, and addresses immediate issues.
10. Product Tracking and Genealogy: This function provides visibility into the location and status of work in progress. Tracks components, materials, production conditions, exceptions, and creates historical records for traceability.
11. Performance Analysis: This function offers the report of manufacturing operations, comparing current results to historical data and expected outcomes. The report contains resource utilization, cycle time, schedule conformance, and overall performance.

Based on the findings of MESA International White Paper Number 1, implementing MES can help factories including but not limited to reducing manufacturing cycle time and minimizing work in progress. Comments on MES implementation include that MES enables companies to determine the next job to run and provides more effective preparation time, resulting in a reduction in setup hours (MESA International 1997b). Taking machining processing as an example, when the engineers know in advance what the next job will be, they can do some preceding work in

advance, like preparing programming codes, jigs (devices installed on machine tools to secure materials), and tools. This preparation helps reduce interruptions during the machine setup process due to missing items, preventing an increase in setup time.

Mehta and Reddy (2015) stated that MES provides many benefits including:

1. Reduce scrap and waste: MES manages the production process and quality that ensures the consistency of the process and quality standard, reduces problems in the product production process, and thereby reduces scrap. For example, MES can provide work instructions to make the operation steps of each production process consistent and reduce the occurrence of defective products through standardized processes. Chen and Voigt (2020) mention that MES leads to focus on reducing non-value-added activities.
2. Capture costs more precisely: MES has data collecting function which can collect production data including labor, scrap, processing time, tooling, etc., which can provide information for cost measurements. Without MES, cost calculations required manual data collection, which was prone to data missing, and no historical record, so cost calculations may be less accurate.
3. Increase uptime: uptime is the time that machine are running for producing. MES includes scheduling and maintenance functions that can help for better arrangement of resources so that resources can be better utilized.
4. Reduce inventory: In the early days without MES, the company may prepare a higher inventory

to deal with uncertain or sudden needs. Utilizing MES, real-time updates in inventory records, including finished goods, scrap, and materials, enable purchasing and scheduling personnel to know what is really on hand. This information guides them to purchase materials at the right time.

5. Improves customer satisfaction: MES can track inventory and machine conditions. This enables manufacturers to locate materials and plan production more easily to meet urgent customer requirements during emergencies.

2-2 ISA-95 and Manufacturing Operation Management (MOM)

International Society of Automation (ISA) and American National Standards Institute (ANSI) developed ISA-95 that defines a framework for enterprise control systems and information exchange structure in 1995. ISA-95's official name is "ANSI/ISA-95 Enterprise-Control System Integration". According to ISA-95 standard, it divides enterprise control into five levels (level 0 to level 4). Level 4 is Business Planning & Logistics, level 3 is Manufacturing Operation Management (MOM), level 2 to level 1 are batch, continuous, discrete control and level 0 is the actual production process which mean the equipment level (see Figure 4).

Figure 4 presents the functional hierarchy model. Each level provides specialized functions and has response times. Level 0 defines the actual physical processes. Level 1 involved tasks related to sensing and manipulating physical processes, usually operating within time frames of seconds and faster intervals. Level 2 involves monitoring and controlling physical processes, and typically operates on time frames of hours, minutes, seconds, and subseconds. Level 3 defines the activities of workflow related to producing the products. Level 3 usually operates within time frames spanning days, shifts, hours, minutes, and seconds. Level 4 defines the business-related activities (for example, order processing, marketing & sales, and product shipping) needed to manage a manufacturing organization and it typically operates on time frames of months, weeks, and day

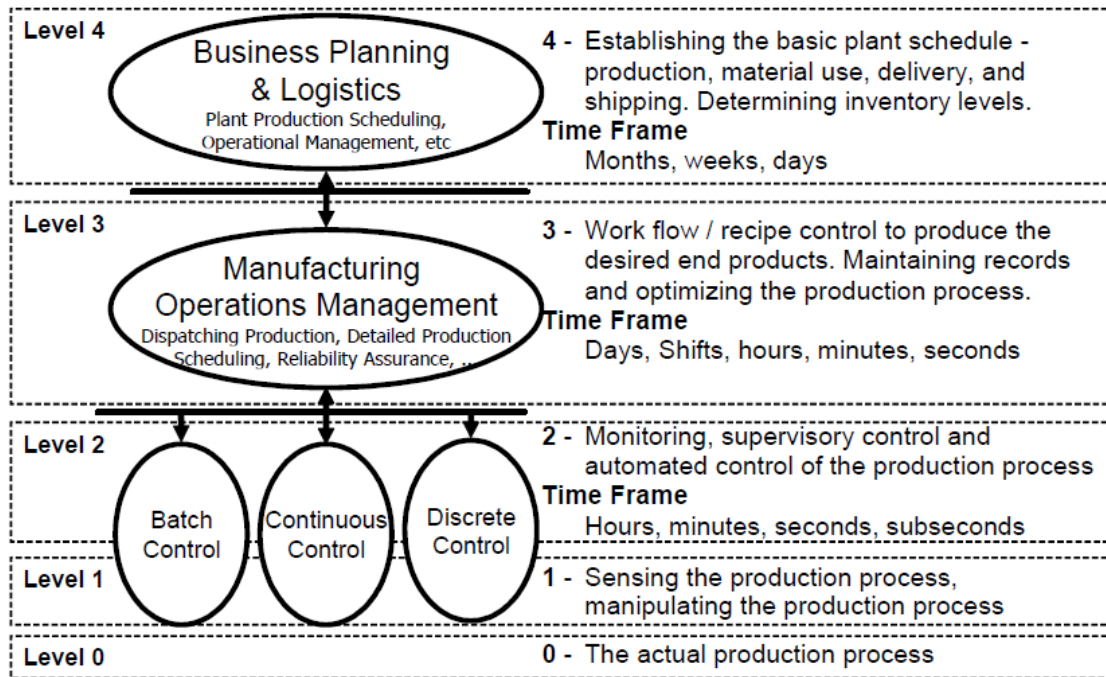


Figure 4 ISA-95 Multi-Level Functional Hierarchy of Activities (ISA 2005)

In ANSI/ISA-95 Part 3, Level 3 MOM involves coordinating personnel, equipment, materials, and energy within a manufacturing facility to transform raw materials or components into finished products. At Level 3, there are four main management aspects encompassed: Production Operation Management, Maintenance Operation Management, Quality Operation Management, and Inventory Operation Management .

In Figure 5, the heavy dotted line indicates the interface between level 3 and level 4. The shaded area indicates the four main management (Production, Maintenance, Quality, Inventory) within Level 3, while the white circles indicate functions within enterprises . The line with arrow represents the information flow. For example, "procurement" placed outside the heavy dotted line means that the activity of procurement is not defined within level 3. The activity of "production

scheduling" placed on the dashed line means that it may be defined both within level 3 and level

4. The basic plant production schedule belongs to level 4, whereas the detailed production scheduling belongs to level 3.

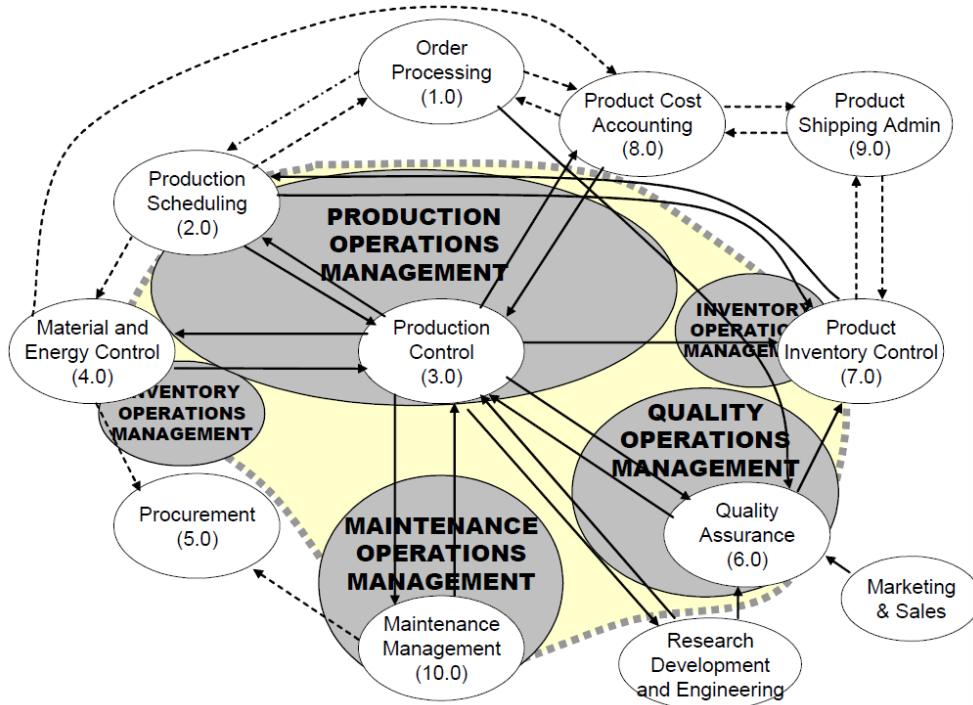


Figure 5 ISA-95 Manufacturing operations management model (ISA 2005)

ISA-95 standard also provides a generic activity model for MOM (see Figure 6). This activity model contains eight activities, (1) Resource management, (2) Definition management, (3) Detailed scheduling, (4) Dispatching, (5) Execution management, (6) Data collection, (7) Tracking, (8) Analysis.

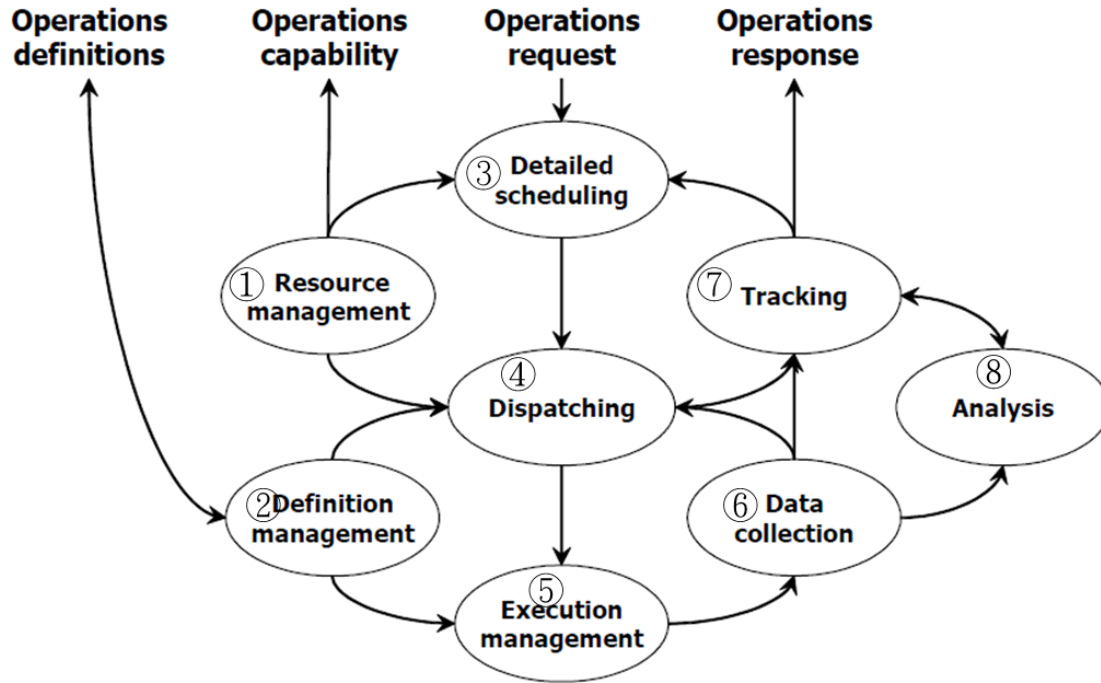


Figure 6 Generic activity model of MOM (ISA 2005)

The ISA-95 standard has gained significant popularity in recent years because it outlines a comprehensive functional model for integrating business and manufacturing layers, and it also defines the information exchange requirements between levels 3 and 4 of the proposed automation pyramid (Mantravadi et al. 2022; Prades et al. 2013). Kent (2018) mentions that “ISA-95 does not define how you do things, it defines what and how information is transferred (Kent 2018)”. But ISA-95 does offer valuable guidance and a framework for facilitating data exchange among production systems (Harjunkoski 2014).

These two terms, MES and MOM, may be confusing. Scholars have offered explanations regarding their distinctions. Some believe they are synonymous, while others consider MES as a subset of MOM (Hughes 2015). Filipov and Vasilev (2016) state that MOM expands MES

capabilities to cover more comprehensive manufacturing processes (Filipov and Vasilev 2016).

Mantravadi et al state that MES can be seen as an application or implementation of MOM

(Mantravadi et al. 2022). Dutta et al. state that MOM is the evolved state of MES (Dutta et al 2022).

In the Jaskó et al.'s article (2020), both MES and MOM are refer to same concept.

MOM is the standard defined by ISA for overall production and operations management (Johnson 2019). ISA-95 aims to establish a set of "consistent terms and information models" to reduce communication gaps among users, minimizing errors or integration issues in systems at different levels (SAP). According to the ISA-95 standard's explanation of the relation between MES and MOM, "ISA-95 standard uses the basic MESA definitions of MES and expands them by adding activity detail and tasks, and extends them into additional operational areas as well as into Maintenance, Quality, and Inventory areas (ISA 2005)

Comparing the MES functional model (Figure 3) proposed by MESA and the MOM activity model (Figure 6) proposed by ISA, we can observe that "Labor management" in MESA's MES functionalities corresponds to "(1) resource management" in MOM; "Resource Allocation and Scheduling" as well as "Operations/Detail Scheduling" in MES functionalities correspond to "(3) Detailed scheduling" in MOM; "Dispatching Production Units" in MES functionalities corresponds to "(4) Dispatching" in MOM; "Process Management" in MES functionalities corresponds to "(5) Execution management" in MOM; "Data Collection/Acquisition" in MES

functionalities corresponds to "(6) Data collection" in MOM; "Product Tracking and Genealogy" in MES functionalities corresponds to "(7) Tracking" in MOM; "Performance Analysis" in MES functionalities corresponds to "(8) Analysis" in MOM. Additionally, "Quality Management" and "Maintenance Management" in MES can correspond to "Quality Operation Management" and "Maintenance Operation Management" among the four major management functions in MOM.

To sum up, after comparing the MES functional model proposed by MESA and the MOM model proposed by ISA, it is found that most of their functionalities can be mutually matched. Therefore, this study believes that MES and MOM do not have significant differences in practical functional aspects. The difference between ISA and MESA lies in the fact that while MESA does not extensively explore the integration of MES with other system levels, ISA offers a more comprehensive explanation of overall enterprise control systems. However, this does not affect the functional role of MES.

2-3 Manufacturing Execution System (MES) Application

In recent years, Manufacturing Execution Systems have been applied in various industries. Chen and Voigt (2020) discuss the MES implementation in food industry. The article mentions that the food industry involves human health, so traceability is a vital aspect. Implementation of MES can enhance process transparency, thereby aiding in improving production efficiency and product traceability. Process transparency and product traceability are better equipped to identify food safety issues as they arise. For instance, if any tainted products emerge, personnel can promptly inspect which specific step in the process is problematic (Chen and Voigt 2020). Menezes, Creado and Zhong (2018) discussed MES that support Radio Frequency Identification (RFID) technology, using RFID for data collection. They pointed out that the traditional paper-based data collection method is not timely and errors often occur, preventing personnel from promptly understanding the shop floor's status. But, the use of smart devices equipped with RFID can address the challenges of untimely data collection. RFID enables real-time data acquisition, eliminating the need for recording on paper and then inputting it into a computer (Menezes, Creado, and Zhong 2018). Mayer, Mehdiyev, and Fettke (2021) proposed a new Computer-aided process planning (CAPP) solution structure, aimed at researching the planning processes. By integrating the MES into the CAPP structure. The main aim of CAPP is to employ computer systems to aid in the planning of manufacturing processes. The historical data collected by MES helps planning and

estimating for CAPP. Due to CAPP relying on a substantial amount of supporting data, Mayer et al.'s (2020) integration of MES into CAPP resulted in a data-driven CAPP solution based on MES data (Mayer, Mehdiyev, and Fettke 2021).

While implementing MES can bring many benefits to company, but implementing MES is not an easy task. Several studies have discussed the challenges that may be encountered during MES implementation and have proposed corresponding solutions (Yue, Niu and Wang 2019; Mantravadi et al 2020; Dutta et al 2022). Yue, Niu, and Wang (2019) mentioned that MES implementation failures could be attributed to factors such as users' inability to accurately express their requirements or a lack of consensus among different departments regarding MES understanding. Therefore, Yue et al proposed a guideline for defining User Requirement Specifications (URS) to mitigate communication barriers between software vendors and users (Yue, Niu, and Wang 2019). Mantravadi, Jansson, and Møller (2020) studied the combination of MES system and artificial intelligence (AI). They applied the function of an AI-based chatbot to MES. In addition to making users more familiar, it can also assist shop floor personnels for making decisions, and the chatbot can also learn from user's input (Mantravadi, Jansson, and Møller 2023).

While MES offers benefits to companies, their practical application is often encumbered by challenges, prompting scholarly investigation into methods for mitigating these impediments (Dutta, 2022). Hence, this study does not directly implement MES software; rather, this study uses

the concept or functionalities of MES and ISA-95 standard to assist in achieving process reengineering objectives.

2-4 Order fulfillment

For measuring a company's product availability, we usually use 3 way, product fill rate, order fill rate, and cycle service level. The order fill rate is the percentage that a company can fulfill the order from its inventory (Chopra, Meindl, and Dawsonera 2013). From the formula below, we can infer that to increase the order fulfillment rate, with the denominator "total order placed" held constant, it is desirable to have the numerator "total order fulfilled from inventory" as high as possible.

$$\text{Order Fulfillment Rate} = \frac{\text{total order fulfilled from inventory}}{\text{total order placed}} \times 100\%$$

The procedure that a company from receiving an order until the product or service is handed over to the customer is referred to as the order fulfillment process (Nanda and Patnaik 2023). The order fill rate holds significant importance because it is relevant to customer satisfaction. Failure to meet our customers' requirements may cause them to seek other suppliers, which means that the company may lose this customer's business (Reid 2022).

The Order fulfillment process is divided into four stages (see Figure 7) including order processing, order planning, order execution and order delivery"(Zhang, Lee, and Xu 2010).

1. Order Processing: This is the first step to understanding customer needs, product specifications

are gathered, and cost and delivery estimates are provided in response to requests. It involves various participants (customers, sales, designers, planners, engineers, etc.) and can be time-consuming and costly due to communication challenges.

2. Order Planning: Order planning includes configuring products and generating process plans for production. Designers, planners, and production engineers are responsible for these tasks.
3. Order Execution: This phase focuses on making the products a reality. It involves preparing materials, setting up production lines, and managing production processes. Production personnel follow the information that is made from previous stages to do the job.
4. Order Delivery: Order delivery entails getting the products to customers and managing inventory.

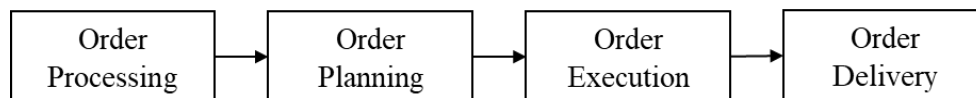


Figure 7 Order Fulfillment Process

Order fulfillment is intricately linked with company revenue. There is some research aimed at improving order fulfillment. Dias et al. (2019) used the concept of lean thinking to take 14 measures for a metalwork company to improve its production process and thereby improve its order fulfillment. By simplifying the process with lean, the results included a 25% reduction in budgeting time, improved communication, streamlined processes, reorganized storage, and reduced logistics times (Dias et al. 2019). In Maia et al. (2019)' s research, it mentioned that the

main reason for the order not being fulfilled is due date delivery failure. The other reasons include wrong product, defective product, and damaged product. It applied the DMAIC cycle to solve the order fulfillment issues in a ceramic company, specifically reducing delivery failures. This study resulted in improved process capacity and a 30% reduction in delayed orders (Maia et al. 2019). Zhang, Lee, and Xu (2010) propose a system called the "integrated order fulfillment system (IOFS)" to improve the order fulfillment process, particularly in situations involving complex information related to customized products. It noted that this system's automation is more effective in representing customer requirements, leading to increased efficiency in order processing. Furthermore, enhanced order fulfillment also means reducing the time and cost required to configure a product (Zhang, Lee, and Xu 2010).

The concept of multi-agent is also utilized to order fulfillment processes. Lin and Shaw (1998) focus on enhancing the agility of the order fulfillment process (OFP) within supply chain networks through the introduction of a multiagent information system (MAIS) approach, aiming to improve efficiency, flexibility, robustness, and adaptability (Lin and Shaw 1998). Nanda and Patnaik (2023) focus on improving order fulfillment in the context of e-commerce and mention that customer satisfaction is related to order fulfillment. Their approach involves proposing a multi-agent coalition-based framework to establish a dependable group of sellers for order fulfillment. The goal is to minimize the fulfillment cost (Nanda and Patnaik 2023).

In summary, we can understand the importance of "process" in order fulfillment. Therefore, this study will start by focusing on the process, aiming to improve the order fulfill rate through production process reengineering.

2-5 Research Contributions

Summarizing this chapter, we acknowledge that the Manufacturing Execution System (MES) functions as an information management system for shop floor operations. It has evolved into a mature and Industry 4.0-compliant tool, facilitating monitoring and control of diverse workshop activities through data collection, integration, and analysis. The ISA95 standard serves as a defining model for enterprise activities. Additionally, as detailed in section 2-4, order fulfillment intricately links to company operations. Current research extensively explores order fulfillment, focusing primarily on process enhancements.

Thus, this study aims to enhance order fulfillment through production process reengineering. This study will propose a guideline for the reengineering process. This guideline can aid small and medium-sized enterprises in identifying and addressing issues related to order fulfillment through reengineering processes. The reference model which is created based on MES plays an important role in the reengineering process, this study also discusses how to apply the reference model in process reengineering by taking a machining factory as an example.

III. Methodology

3-1 Research Framework

In order to enhance the order fulfillment of the company, this study proposes the use of production process reengineering as a method for improvement. Consequently, this research will present a guideline for reengineering the production process (detailed in section 3-3) aimed at providing a step-by-step approach for enterprises. This guideline comprises three steps: firstly, identifying potential causes within the enterprise that may lead to low order fulfillment; secondly, reviewing the current production processes and identifying issues within the process; and thirdly, applying the referenced model to the current processes to improve identified issues. This reference model is based on MES and the ISA95 standard (detailed in section 3-4). Figure 8 illustrates the three steps of the guideline, while Figure 9 illustrates the establishment of the reference model and how the third step of the guideline applies this reference model to the current production process.

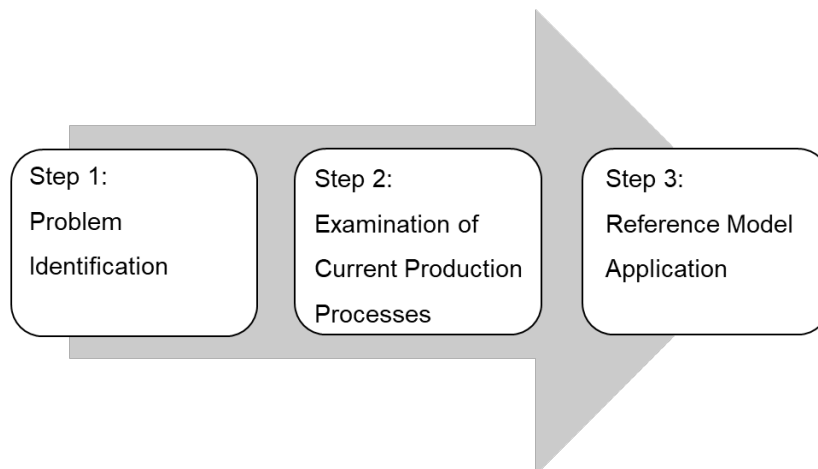


Figure 8 Three Steps of Guideline for Reengineering Production Process

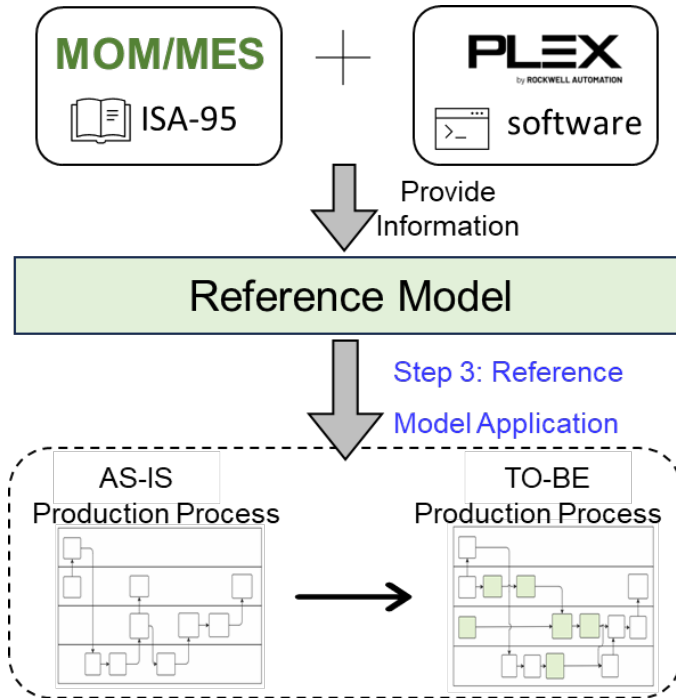


Figure 9 The Establishment of Reference Model and Application

3-2 Model Assumption

1. There are many reasons that affect enterprise order fulfillment rate. This study primarily focuses on the production aspect with the objective of improving order fill rates. Other areas, such as finance, human resources, and logistics supply chain, are beyond the scope of this research.
2. This study focuses on the production process, hence within the four management areas of MOM, this study chooses production operation management as a reference model foundation. Maintenance, quality, and inventory operation management are outside the scope of this research.
3. This study only considers the information required for each activity, ensuring that each piece of information is established and conveyed. While the model includes scheduling and dispatching, we do not delve into the rules governing scheduling and dispatching. The principles of scheduling and dispatching are not within the scope of this study.

3-3 Guideline of Reengineering Production Process

This study aims to assist small and medium-sized enterprises in improving their order fulfillment through production process reengineering. Here is a guide to reengineer the process (refer to Figure 8):

1. Problem Identification

The primary task of this step involves identifying the reasons causing low order fulfillment through brainstorming. Engaging internal staff in brainstorming sessions helps in exploring potential causes for the inefficiencies in order fulfillment. This collective discussion aids in uncovering various potential issues. Once all issues are gathered, they are categorized and analyzed to establish causal relationships among them. This process can be presented using methods like the fishbone diagram, causal loop diagram, or why tree.

2. Examination of Current Production Processes

Subsequently, it is necessary to examine the current production processes of the company to determine any improper or missing steps. By drawing the current production process flowchart, individuals can highlight the issues encountered at each step. Specifically, this involves identifying obstacles that might hinder the work. For instance, an operations personnel might indicate occasional negligence of certain steps during the production process, resulting in compromised product quality or reduced production speed.

3. Reference Model Application

Upon identifying the problems, refer to the reference model presented in this study (refer to section 3-3) and select suitable modules to apply to the current production processes. This step main is integrates the reference model into the current production processes to address the identified issues.

3-4 Reference Model

ISA-95 defines MOM as encompassing production, quality, maintenance, and inventory management. Due to the focus of this study on the reengineering of the production process, only the production operation management content will be selected as the foundational basis for establishing the reference model (see Figure 10).

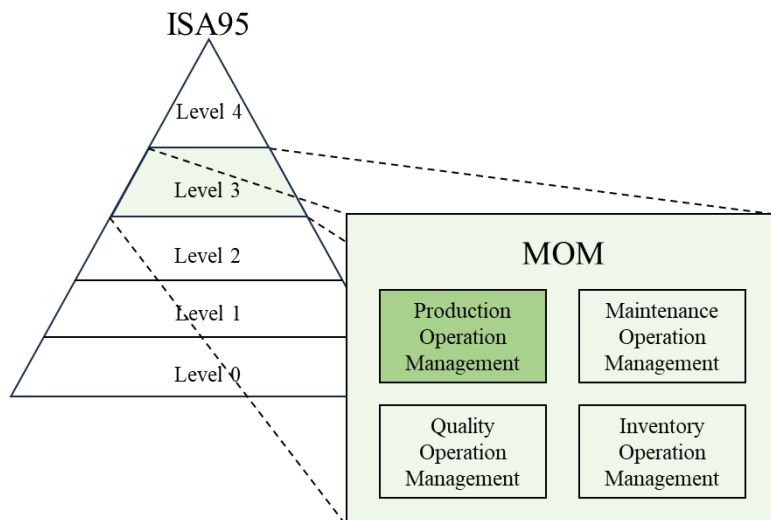


Figure 10 ISA95 and MOM Structure Diagram

The production operation activities are defined into eight activities. These eight activities will serve as the primary framework for constructing the reference model in this study.

Regarding the MES component, this research will practically utilize the Plex software which is provided by Rockwell Automation to ascertain which information within the production messages is required and which is optional. Specifically, during the software operation, the system fails to function if any step is missed. The step missed may cause data missing, and we can know what information is required through it.

The collaboration between the ISA-95 standard and the Plex software compensates for information that the MES software might overlook. MES assists in delineating which information holds significant importance. The detailed information provided by ISA95 might not all be essential. Moreover, ISA-95 does not offer specific guidelines for the actual integration of this information (Kent 2018), especially considering that the excessive details provided by ISA-95 might be overly abstract and challenging for enterprises.

In the ISA95 standard, the activity model for production operation management is depicted in Figure 11. Each ellipse represents an activity, and the lines between ellipses are information flow. There are a total of eight activities, namely (1). Product Definition Management, (2). Production Resource Management, (3). Detailed Production Scheduling, (4). Production Dispatching, (5). Production Execution Management, (6). Production Data Collection, (7).

Production Tracking, and (8). Production Performance Analysis.

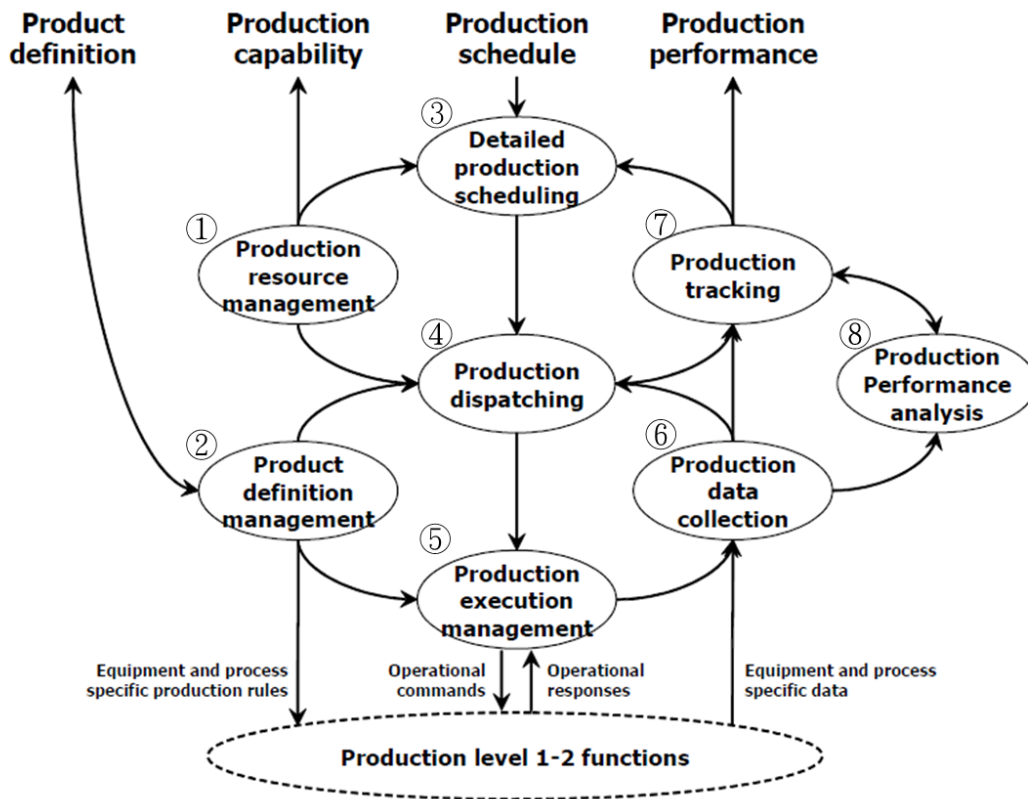


Figure 11 Activity Model of Production Operation Management of MOM

1. Product Definition Management

Product Definition includes basic product information, product structure, and production routings. Certain information on product definition can be received from level 4. Basic product information for example. The basic information includes customer, material, type (series), and others. There is usually a product drawing as a supporting document. The product structure refers to the composition of the product, usually with a BOM (Bill of Material) as a supporting document. Production routings (or processing routing) means the specific

production processes required for the product, including machining steps, manufacturing methods, equipment selection, and more. The focus is on "how to make this product." The same product may have different production routings in different manufacturers. Processing routing information will be provided to activities of scheduling, dispatching, and execution.

Figure 12 presents the information structure of the product definition. This information should be documented and managed during the product development phase. The absence of this information can lead to unnecessary costs. For example, during the first time production of a product, the company should document details such as setup time, processing time, and standard capacity. This information is crucial for production personnel to perform scheduling tasks for next time. If the processing time information is missing or unrecorded, it might influence scheduling tasks for the next time.

Figure 13 shows information flow in the activity of product definition management. Typically, after receiving an order, sales personnel should establish product information and convey this information to engineers and production managers. Engineers will then create more detailed product information (e.g., processing routings) based on the information provided by the sales team. Some companies may conduct testing before establishing processing routings, while others may not. Hence, this diagram needs to be adjusted based on the actual circumstances. The actors may be different in different companies.

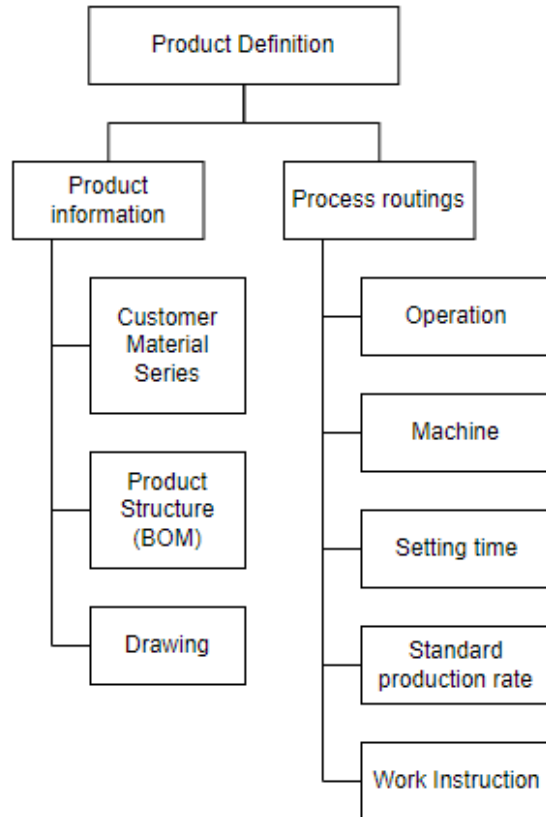


Figure 12 Information Structure of Product Definition

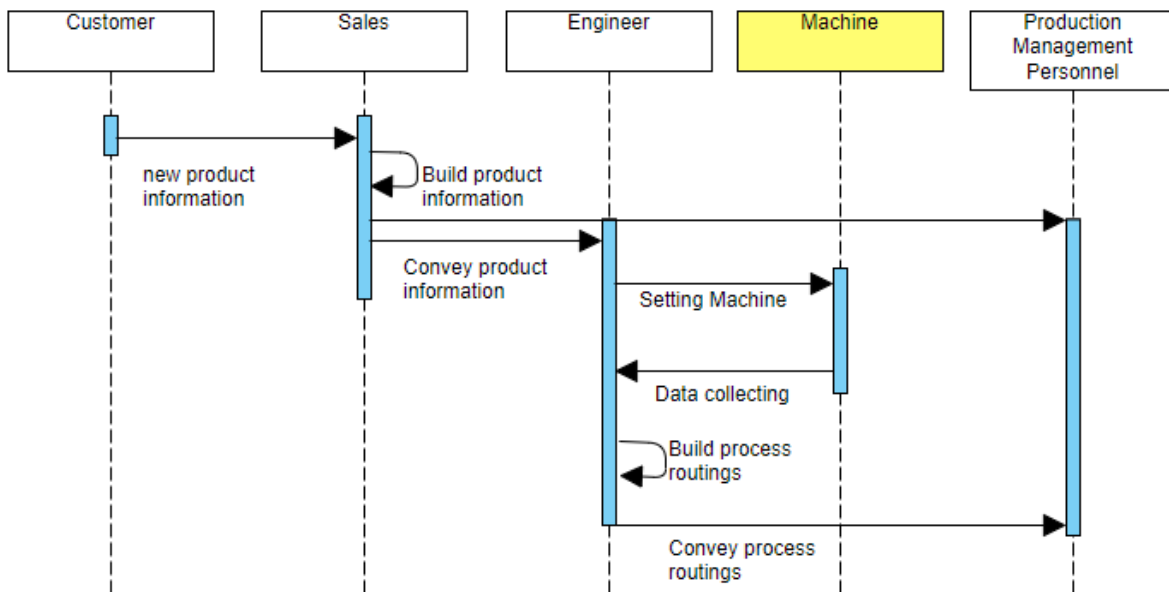


Figure 13 Information Flow in the Activity of Product Definition Management

2. Production Resource Management

Production resources encompass all the various elements utilized in the production process, including machines, tools, labor force, materials, and energy. The tasks of Production Resource Management include "Defining production resources" and "Providing information on resource capability". "Defining production resources" involves specifying the application scope and conditions for each resource. To be more specific, for instance, worker A may specialize in producing three specific products—A, B, and C. Machine A might only manufacture products made from particular materials. Machine B may be limited to producing products within certain size ranges. These information belong to resource definition. Additionally, determining quantities of resource is required. This refers to the count of equipment, human resources (operators, engineers), and materials available within the factory premises.

The aspect of "Providing information on resource capability" involves understanding the operational status of equipment, such as being in production, set-up, idle, or under maintenance. Regarding personnel status, it necessitates complementing data provided by the human resources department to determine factors like employee absences or leaves for a given day. The information on resource capabilities is utilized by the activity of scheduling.

In addition to the information offered by ISA95, Plex has revealed another information

required: "Operation." Operations are core functions that add value performed by the company. The operation will associated with the process routing of products. Figure 14 shows the Information Structure of Production Resource. Figure 15 shows the information flow between related personnel. The actors may be different in different companies. In Figure 15, we can see that human resource personnel provide operator information, warehouse or inventory management staff offer material details, and engineers provide equipment capabilities and operation information to production management personnel. The production management personnel then consolidate this information and build the resource information database.

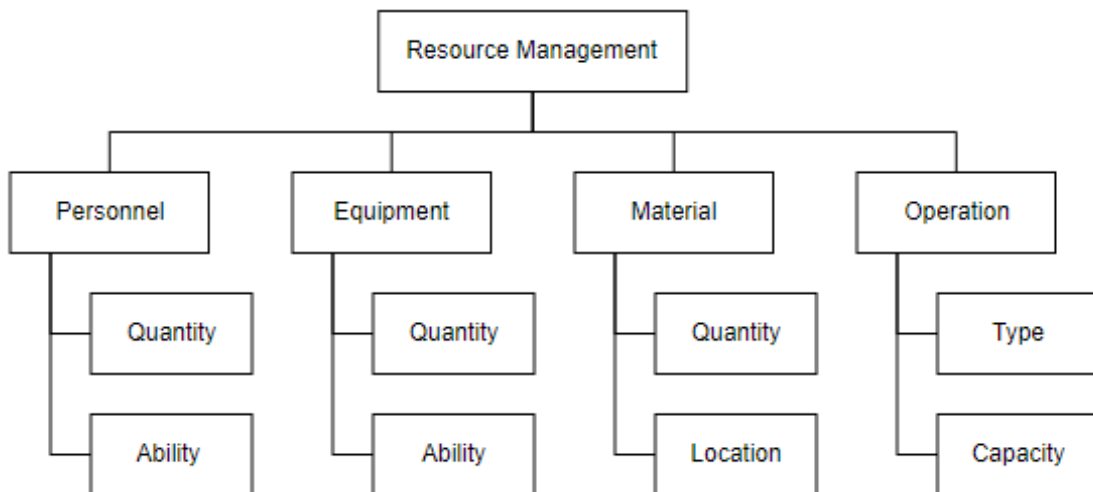


Figure 14 Information Structure of Production Resource

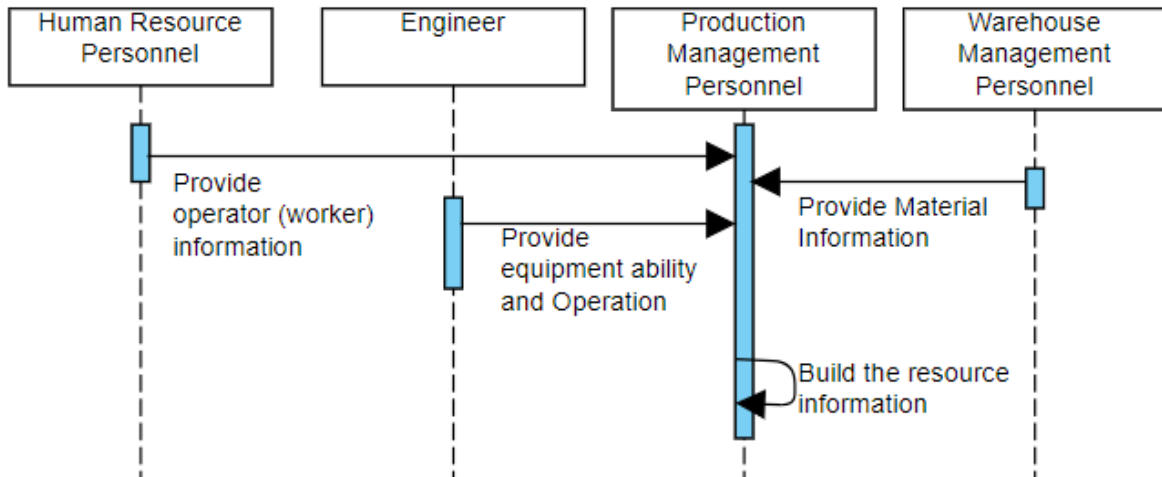


Figure 15 Information Flow in the Activity of Resource Management

3. Detailed Production Scheduling

Detailed production scheduling refers to the optimal use of resources to meet the requirements of the production plan. The Production Plan provided by the ERP might contain limited information, such as product delivery dates, and production start and end dates of production. However, it may lack detailed schedules for intermediate steps within the product, which is the activity of Detailed Production Scheduling. Creating a detailed production schedule involves according to the Production Plan from Level 4 (ERP) and establishing a more detailed schedule. During this activity, the task includes creating a more detailed production plan by considering the production plan from level 4 and the information from the product definition and resource management (see Figure 16). In the process of detailed production scheduling, it might be necessary to split or merge the Production Schedule. Figure 17 is the information flow diagram in detailed production scheduling. Sales (or ERP)

will convey the production plan (or due date table) to the production management personnel.

Then the production management personnel will use the information created in the previous activities, "product definition" and "resource management", plus the production plan provided by Sales to create a production schedule. Due to the "product definition" and "resource management" are not belonging to this activity, Figure 17 didn't show these parts.

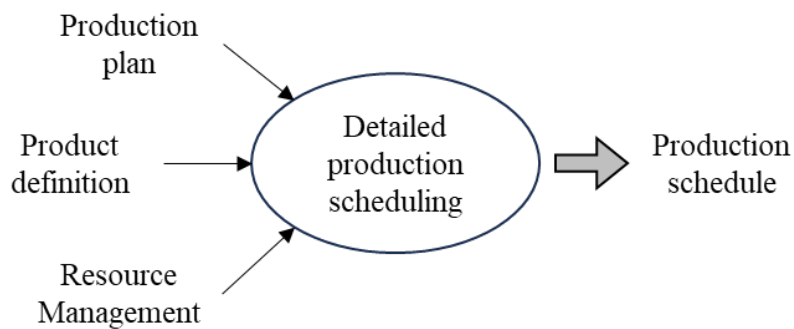


Figure 16 Required information for Detailed Production Schedule

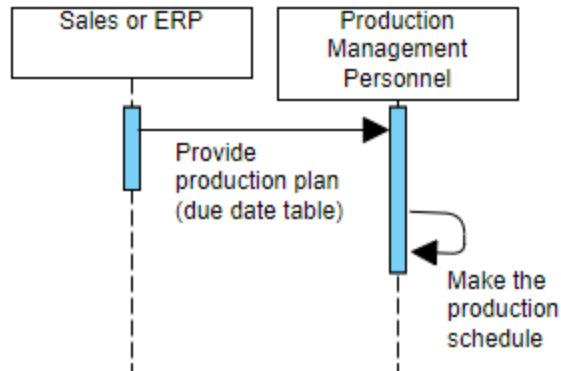


Figure 17 Information Flow in the Activity of Detailed Production Scheduling

4. Production Dispatching

Production dispatching involves allocating jobs outlined in the production schedule to available resources. This activity encompasses assigning materials, equipment, and personnel required to execute a production work order. Figure 18 illustrates the required information for the activity of production dispatching to generate the dispatch list. Figure 19 shows the information flow in production dispatching. The production manager hands the dispatching list to the person responsible for the work, usually an engineer or operator.

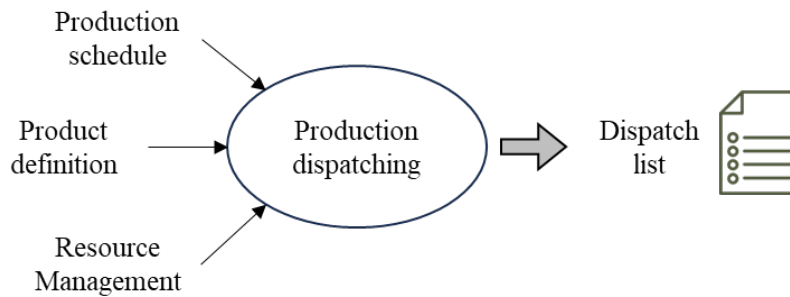


Figure 18 Required information for Production Dispatching

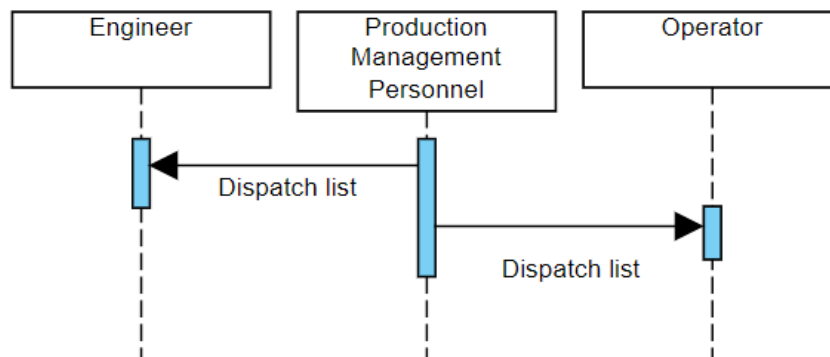


Figure 19 Information Flow in the Activity of Production Dispatching

5. Production Execution Management

Production execution management involves directing the tasks outlined on the dispatch list. Figure 20 shows information flow in production execution management. For example, When the engineer receives the dispatch list from production management personnel, the engineer starts executing the job (setting machine for example) on the dispatch list. During execution of the job, the support of the work instruction is required (refer Figure 21). The work instruction is established in the product definition activity. When the engineer completes the job, it will be reported to the production management personnel, who will then send the dispatch list to the operator. The operator usually also needs work instructions when executing jobs.

Figure 21 illustrates that when an engineer receives a dispatch list, the task specified on it might involve setting up a machine, and executing this "machine setting" correctly stands as the primary objective of production execution. This task typically requires work instructions as resources to guide the process. For machine setting, these work instructions might include machine operations, coding, parameter settings, and selection of cutting tools, among other details. Engineers follow these instructions to carry out the task. Work instructions establish a standardized operational procedure, reducing errors during task execution and providing better control over the entire process.

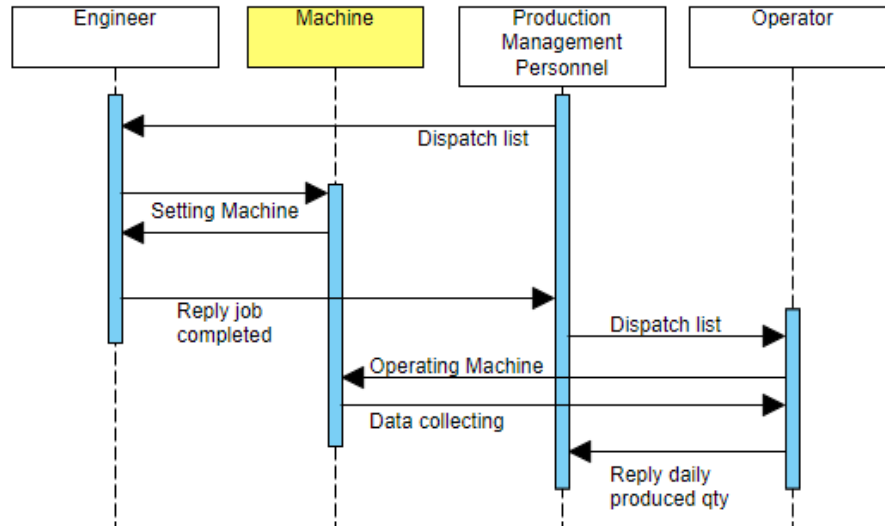


Figure 20 Information Flow in the Activity of Production Execution Management

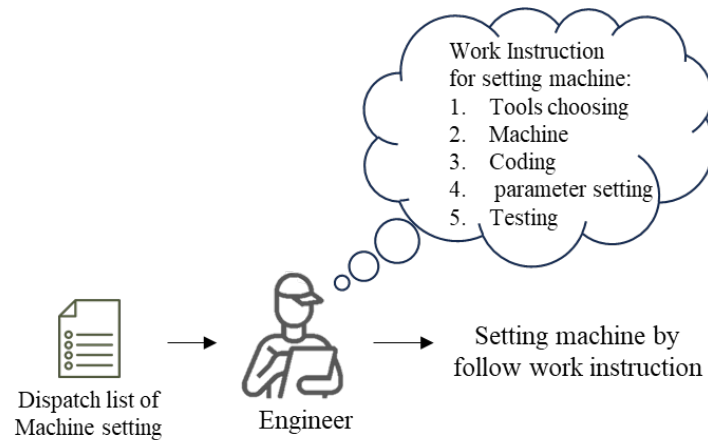


Figure 21 Execute the Job on the Dispatch List Diagram

6. Production Data Collection

Production Data Collection refers to the gathering of specific data within the production process. The data collected comprises production information obtained from execution activity and data from levels 1 to 2 (including resource data, operations data, equipment status, equipment configuration, alarms, operator actions, and operator comments). This data can be recorded manually by personnel or directly collected from equipment controllers. The

collected data is provided to Production Tracking activity and Production Performance Analysis activity.

7. Production Tracking

Production Tracking is an activity that involves preparing for production responses. This process utilizes historical data provided by production data collection to generate reports on production performance, then transmitted to Level 4. Within the Production Tracking activity, it is crucial to summarize and report the actual resources used during the production process, feeding this information back into the production scheduling activity. For example, the current production output quantity and work-in-progress (WIP) quantity will be replied to the scheduling activity, enabling scheduling personnel to adjust the production schedule as needed. Figure 22 shows the information flow in production tracking. In general production process, the operator will reply the daily product produced quantity to the production management personnel who may consider adjusting production schedule if required. Then, the production management personnel will convey the adjusted production schedule to sales who may reply to customer if the delivery date may be changed. In addition to produced quantity, operators also reply the production status to the production management personnel and make them generate production performance reports.

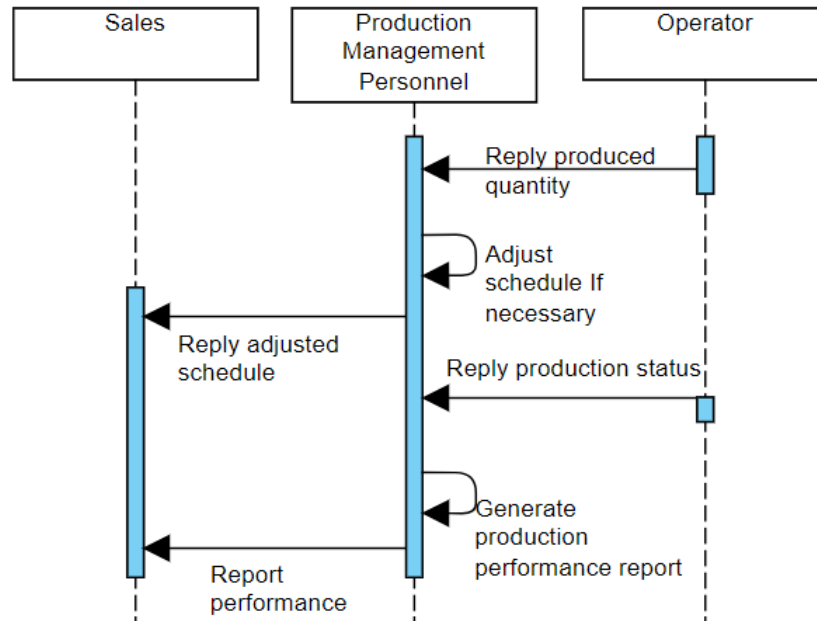


Figure 22 Information Flow in the Activity of Production Tracking

8. Production Performance Analysis

Production Performance Analysis refers to the analyze and report performance information to business systems. This activity involves analyzing resource utilization, such as equipment, materials, manpower, and production processes. The analysis reports serve as a basis for technical personnel to enhance future manufacturing processes.

For instance, (1) a production management supervisor or product manager might compare the performance of different production lines to assess which manufacturing method is more effective. Based on these findings, process improvements can be implemented. (2) By consolidating multiple performance reports, key production indicators can be established. Be specifically, actual production quantities are not only influenced by processing times but

also by the operators. Variations in operators' production speeds and factors like personnel breaks can result in varying output quantities for the same product. Recording daily actual output quantities and deriving averages can serve as a production indicator and help for assigning production operators. (3) This activity also involves analyzing the utilization of equipment resources and providing procurement personnel with insights when acquiring new equipment.

Some activities mentioned earlier that lack an information flow diagram are discussed in Figure 23. Figure 23 integrates the information flow of the aforementioned eight activities, illustrating the entire information flow during the production process. It's important to note that different companies or industries may have variations, and this information flow diagram is based on the example of the machining industry.

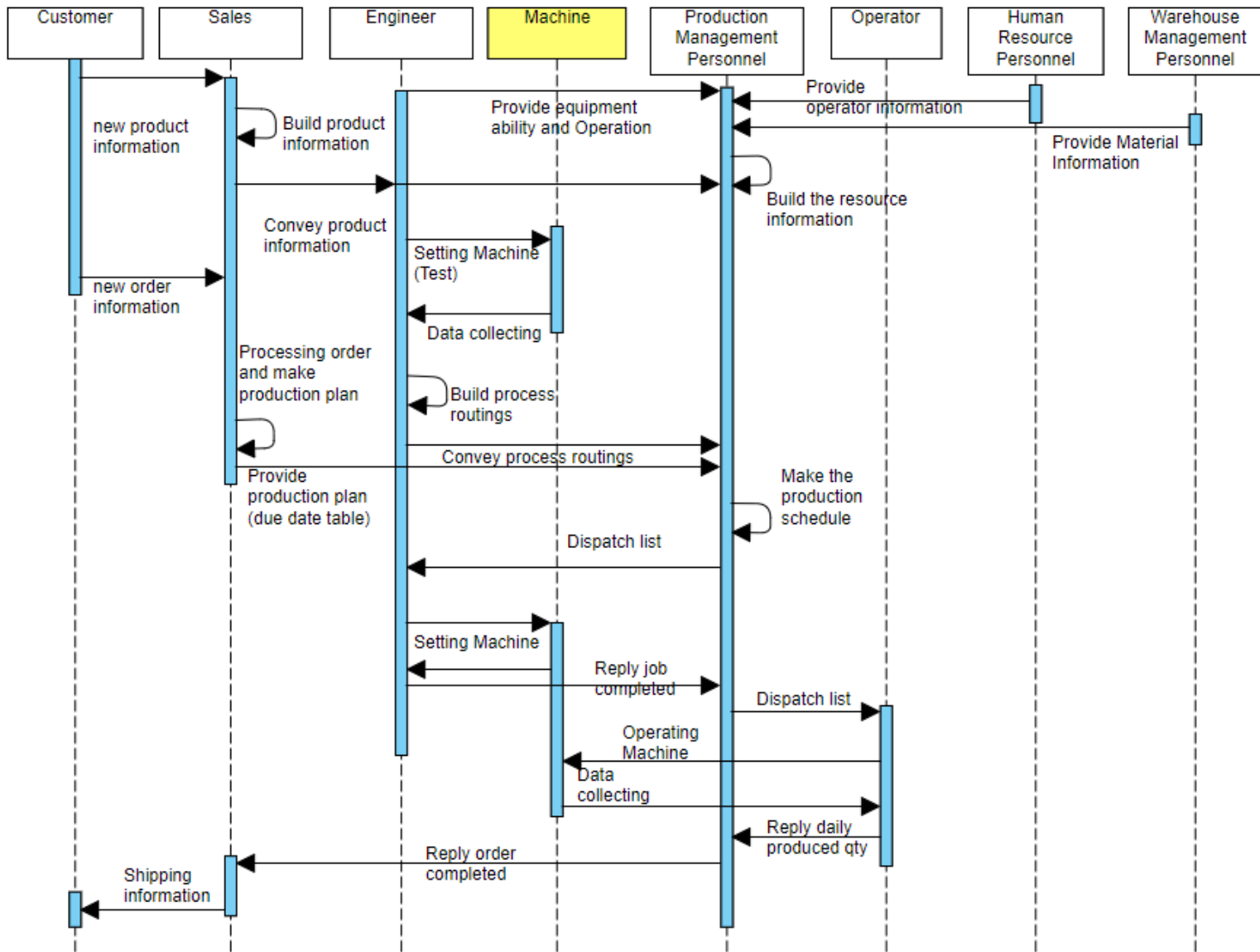


Figure 23 Information flow of Production Process

Table 1 Summary of Reference Model

Activity	Main Task
(1). Product Definition Management	Build the product definition (refer to Figure 10)
(2). Production Resource Management	Build the resource information (refer to Figure 12)
(3). Detailed Production Scheduling	Make the production schedule based on ① Production plan, ② Production definition, ③ Production resource
(4). Production Dispatching	Assign resource to job then make dispatch list based on ① Production schedule ② Production definition, ③ Production resource
(5). Production Execution Management	Execution the job on dispatch list correctly based on ① Dispatch list ② Production definition ③ Work Instruction
(6). Production Data Collection	Collect the specific data within the production process includes ① Dispatch list ② Production definition
(7). Production Tracking	Know the production situation and report to level 4 and scheduling activity. ① Actual resource used ② Actual quantity of produced products, WIP
(8). Production Performance Analysis	Analyze production performance include ① Resource utilization ② Production efficiency

IV. Application

In Chapter 4, this study presents the background of the case company in Section 4-1. Subsequently, it follows the three steps of the guideline proposed in Section 3-3 to reengineer the processes of the case company. Sections 4-2 to 4-4 correspond to each of these three steps, respectively. Section 4-5 is brief summary of this chapter.

4-1 Case Introduction

This study takes a small and medium enterprise (SME) in Taiwan, specializing in metal processing and manufacturing as a case study for the implementation of the reengineering production process in its production operations. The company this study selected will be referred to as "Company Y."

Company Y is an original equipment manufacturer (OEM) in Taiwan. The products of Company Y include auto parts, bicycle parts, medical equipment parts, etc. Company Y provides machining services but does not have its own designed products. The strategy of low-margin, high-volume sales is the current way to generate profits in Company Y.

The general product processing flow of Company Y is roughly as follows (see Figure 24). First of all, Company Y purchases raw materials from material suppliers, then sends the materials to a heat treatment facility for heat treatment (a way to change the physical properties of the material) according to customer requirements. Afterward, the materials return to Company Y's

factory for the machining process. The finished products are then sent to a surface treatment facility for surface treatment, such as anodizing, abrasive blasting, and baking paint, with the aim of altering the surface condition of the products. Finally, the products undergo outgoing quality control (OQC) within the factory and then are packaged for shipment. Machining using milling machines and lathes constitutes the primary business of Company Y, as well as being the main source of income. Therefore, the focus of this study will be on discussing the machining process. Outsourcing parts are not the primary factor influencing Company Y's order fulfillment, primarily because the suppliers for Company Y are adequate. In cases where suppliers are unable to provide service or deliver on time, Company Y can explore alternative suppliers to meet its requirements.

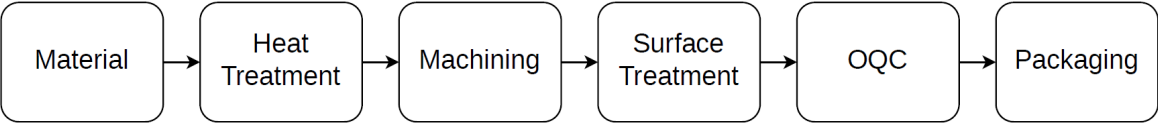


Figure 24 Product processing flow of Company Y

The organizational structure of Company Y is as shown in the Figure 25, which is a typical structure for many small and medium-sized enterprises in Taiwan. The top level of the company is led by the president (boss), who can contact all employees directly, and Vice versa. The president is at the highest level, and leads the administrative department, processing department, and quality control department. The processing department is further divided into milling and turning departments, based on different machining processes.

This study aims to reengineer the production process of Company Y by utilizing existing personnel, without hiring additional employees (as new hires would increase costs) and minimizing the added workload for current employees. The relevant personnel who will be involved in the production process reengineering include sales and production management specialists in the administrative department, and engineers and production management personnel in the processing department.

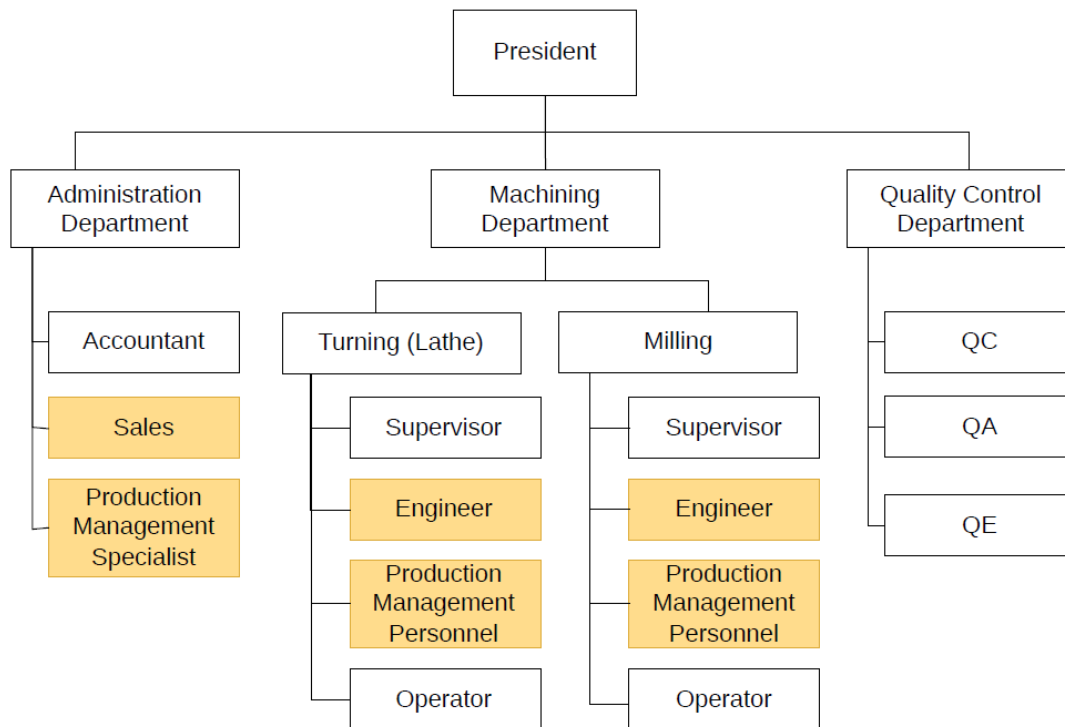


Figure 25 Organization Chart of Company Y

Selecting Company Y as a case because that Company Y has the typically characteristics of SMEs in Taiwan. SMEs in Taiwan often lack management expertise and resources, and they may not fully understand the concepts of digital transformation and digitization.

However, Small and medium-sized enterprises hold significant importance in Taiwan's economy. According to the White Paper on Small and Medium Enterprises in Taiwan (2020), in 2019, Taiwan had a total of 1,491,420 small and medium-sized enterprises (SMEs), which comprised 97.65% of all enterprises in Taiwan. In 2019, Taiwan's SMEs employed a total of 9,054,000 individuals. SMEs accounted for 78.73% of the total employed persons.

Moreover, Taiwan faces a serious issue of declining birth rates , coupled with a reluctance among young people to engage in the production side of the manufacturing industry. This has resulted in a shortage of manpower in factories, and automation become the trend. Additionally, shorter product life cycles and tighter deadlines have compelled SMEs in Taiwan to enhance their production efficiency in order to improve competitiveness (Hung et al. 2019).

Thus, this study aims to assist SMEs in improving their operation by providing a low-cost and easily implementable solution through the implementation of a reengineering production process.

4-2 Problem Identification and Discussion

In first step of reengineering production which we mention in section 3-1, companies should try to find the problem that may cause low order fulfillment. By brainstorming with the participation of Company Y's supervisors, engineers, sales personnel, and production management personnel, find the problems inherent may cause low order fulfillment. Figure 26 illustrates the possible reasons for causing Company Y's low order fulfillment by why tree.

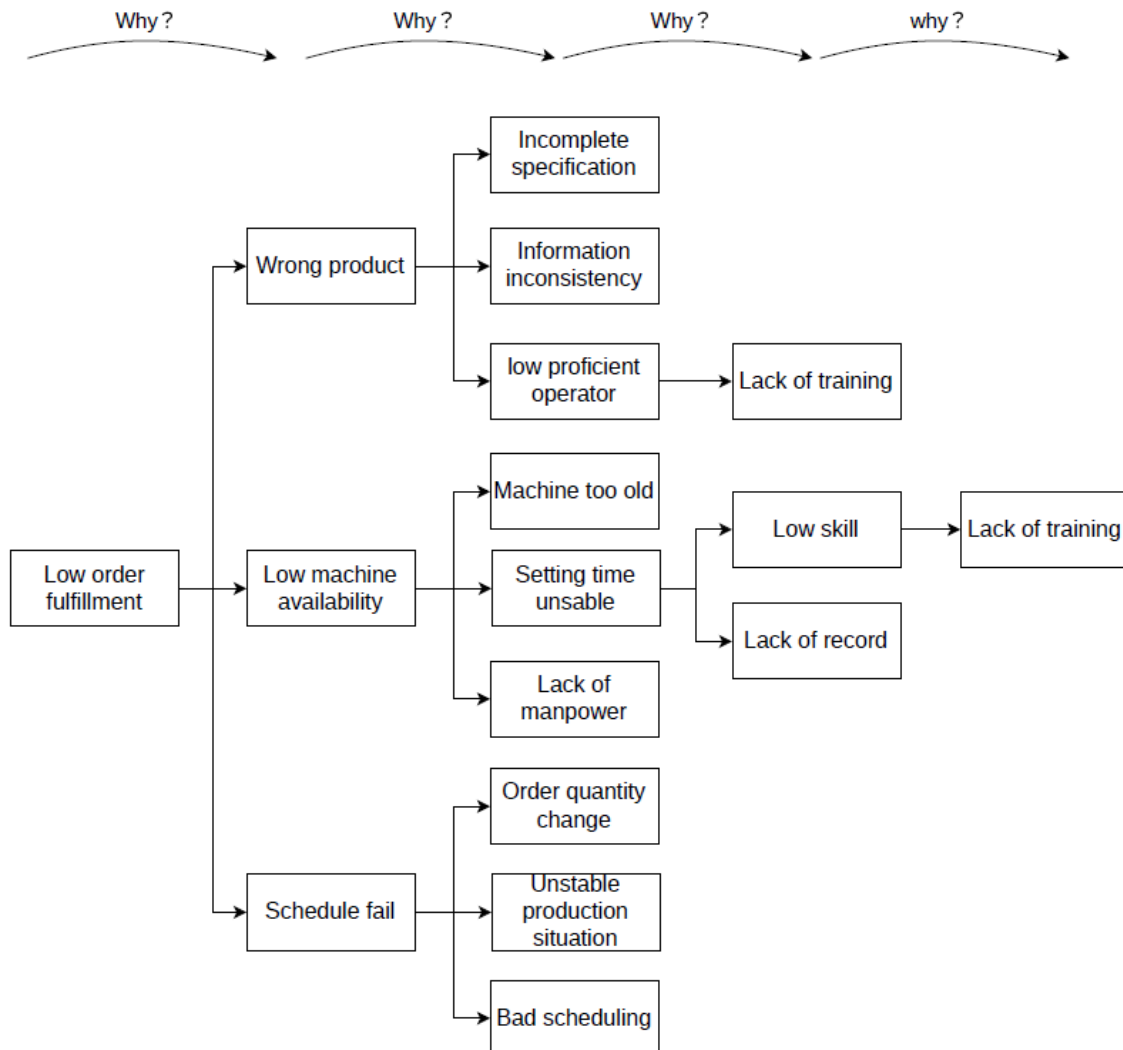


Figure 26 Why Tree of Low Order Fulfillment

According to brainstorming result, there are three main reasons resulting in low order fulfillment. They are “Wrong product”, “Low machine availability” and “Schedule fail”.

1. Wrong Product:

This refers to defective items or the production of incorrect products (different items). One of the reasons is that incomplete specifications contribute to wrong product occurrences due to the absence of comprehensive guidelines for quality control personnel, leading to mistakes in inspection procedures. Information inconsistency is another cause, where production management personnel might fail to accurately communicate required production quantities or items to operators, resulting in excessive production or wrong products produced. Moreover, low proficiency among operators during production processes, possibly due to errors or missed steps, can result in defective products. This proficiency issue might be related to inadequate training within the company.

2. Low Machine Availability:


This denotes instances where Company Y's equipment frequently remains idle, an unfavorable situation for its operations. Several reasons contribute to low equipment utilization, including outdated machinery and poor precision, limiting the range of producible items. Unstable setting times also play a role; inconsistent setting times by different engineers with varying levels of familiarity handling these settings may disrupt scheduled production

plans. The lack of records documenting previous settings could force new engineers to start from scratch. Additionally, insufficient operator availability for production contributes to low machine availability.

3. Schedule Fail:

This describes situations where actual production deviates from pre-established schedules. Company Y mentioned three potential reasons behind schedule failures. Firstly, last-minute alterations in order quantities or deadlines by customers might extend the production time originally planned for two days to three. Secondly, the unstable production situation means that unexpected events happen causing unplanned downtimes, such as equipment failures, sudden employee absences, or production halts due to poor quality. Lastly, bad scheduling indicates that the initial planning may be not good enough. The situations may be miscalculations of due date or improper resource allocation.

4-3 Examination of Current Production Processes

After conducting the brainstorming session based on the previous step, we have identified potential causes for the low order fulfillment. Next, the second step is to outline the current production process and attempt to identify potential issues within the workflow. Through production process and attempt to identify potential issues within the workflow. Through brainstorming with the participation of Company Y's supervisors, engineers, sales personnel and production management personnel, the problems inherent in the current production process may cause low order fulfillment. Figure 27 illustrates the current production process of Company Y. The bomb icons labeled as "  " in the diagram indicate the obstacles that might affect the work during the production process. The obstacles were pointed out by the relevant personnel.

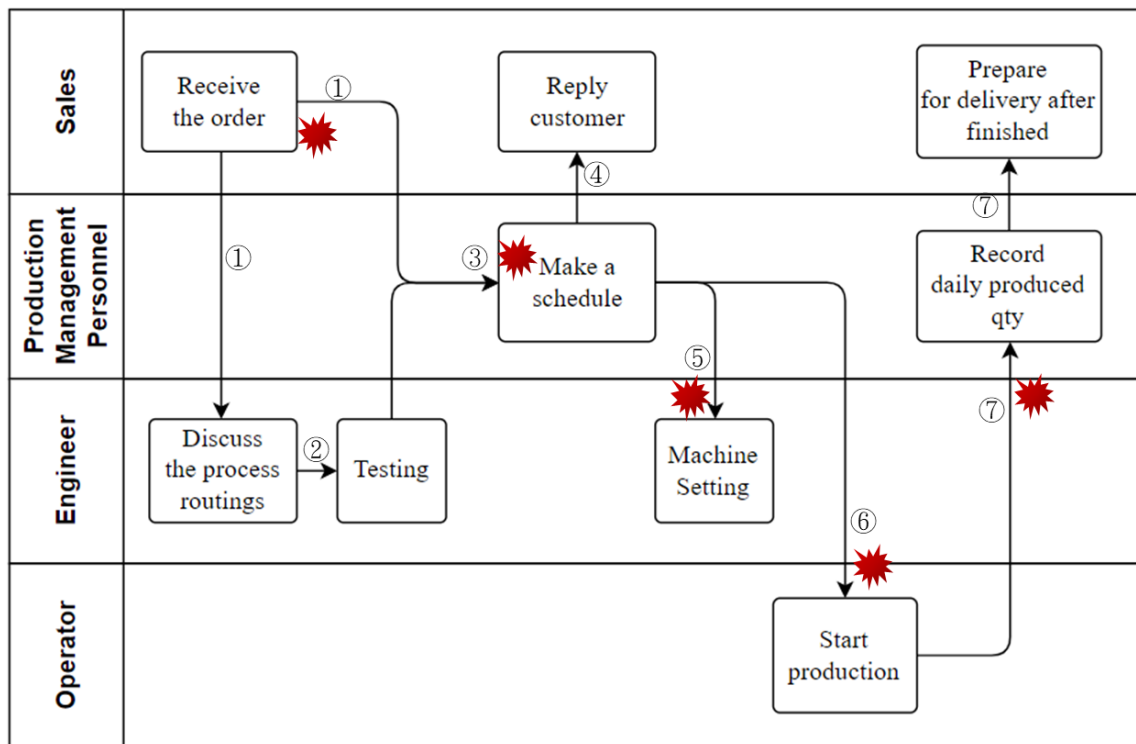




Figure 27 Currently Production Process Flow Chart (As-Is)

The process is explained as follows:

1. After receiving an new order from customers, the sales personnel informs the engineers and production management personnel. Then the engineers will discuss and define the process routings for the product.


Bomb : The sales personnel at Company Y mentioned that engineers and production management personnel sometimes need to ask them the same questions repeatedly. These inquiries typically concern the material of a product and whether it has any specific requirements, even though these products are not new and have been produced previously. However, both parties tend to forget these details, necessitating them to reach out to the customers again for clarification. This situation occasionally raises concerns that the customers might feel bothered by the repeated questions.

2. Once the process routings are finalized, engineers conduct tests to define setup time and production standard rate.


Bomb : Company Y had experienced an event related to process routings. For example, for a product with five operations in the process routings, due to personnel negligence, one of the operations was skipped, resulting in missing processing steps and the production of defective items.

3. Production management personnel makes the production schedule based on the order delivery date from the order information provide by sales personnel and processing time information,

process routings provided by engineers.


Bomb : The production management personnel have mentioned that when crafting production schedules, they take into account the setting time. However, the setting time can vary when different engineers execute the task, and sometimes, even with the same engineer, the setting time tends to be inconsistent. This inconsistency in setting times poses challenges for production management when scheduling. Moreover, the data regarding setting times is not documented or systematically managed; it is solely recorded in personnel's notebooks or relies on experiential judgment. This lack of centralized documentation may lead to risks such as missing data or requiring new employees to invest a significant amount of time in familiarizing themselves with the situation. There are instances where setting times change, but only engineers are aware of these alterations, resulting in production management personnel failing to promptly update this crucial information.

4. With the production schedule determined, production management personnel conveys the estimated finished date to the salesperson for the negotiation information with the customer.
5. Engineers start machine settings according to the schedule provide from production management personnel .

Bomb : The engineers mentioned that sometimes the time taken for a setting test differs from the actual time required during production settings. This variance could be due to


previous instances where steps were not documented during the setting test. Additionally, when a different engineer takes over, their varied technical expertise and operational methods might contribute to differences in setting times. Senior engineers tend to spend less time on setting compared to engineers or assistant engineers. If senior engineers can share their methods with other engineers, it might help in reducing the variability in setting time.

6. After completing machine settings, production management personnel dispatches workers for production.

Bomb : During the production execution process, there are instances where defective products are produced. As discussed in section 4-2, the reasons could be attributed to insufficient proficiency among the operators or instability in the machinery. Operators have indicated that at times, they forget certain operational steps, leading them to spend additional time seeking guidance from colleagues, consequently decreasing productivity. Moreover, experienced operators may spend time to guide less experienced ones to deal with problems, potentially resulting in decreasing productivity as well. Engineers have also highlighted that addressing issues during the production execution process may disrupt their primary tasks. This interference might also contribute to the previously mentioned inconsistency in setting times.


7. During the period of production, the production management personnel will count the daily

produced quantity and report back to the salesperson.

Bomb : Both sales and production management personnel have mentioned that Company Y may need a reliable approach to quantity statistics in production. Company Y has encountered instances of quantity statistics errors due to various reasons. In one scenario, boxes were sealed prematurely before being filled, and new boxes were used to accommodate the following items. At the end of the production day, when counting quantity, the possibility of some boxes being incompletely filled was overlooked. Additionally, there was an incident where operators mistakenly included products produced from the previous day (which had already been counted before) in the count, resulting in a duplication of the count.

4-4 Reengineering Production Process

The first two steps identified potential reasons for the low order fulfillment at Company Y.

The third step involves integrating activities from the reference model into the current production process to address the problems. The location of the activity added will be guided by the positions indicated by bomb icons () on the current process as a reference. Figure 28 illustrates the reengineering production process.

Notes:

1. The shaded blocks refer to the additional steps introduced in the reengineering production process as compared to the current production process.
2. Blocks with dotted line borders mean procedures that may not occur in every production cycle, typically happening only during the initial production of a new product.

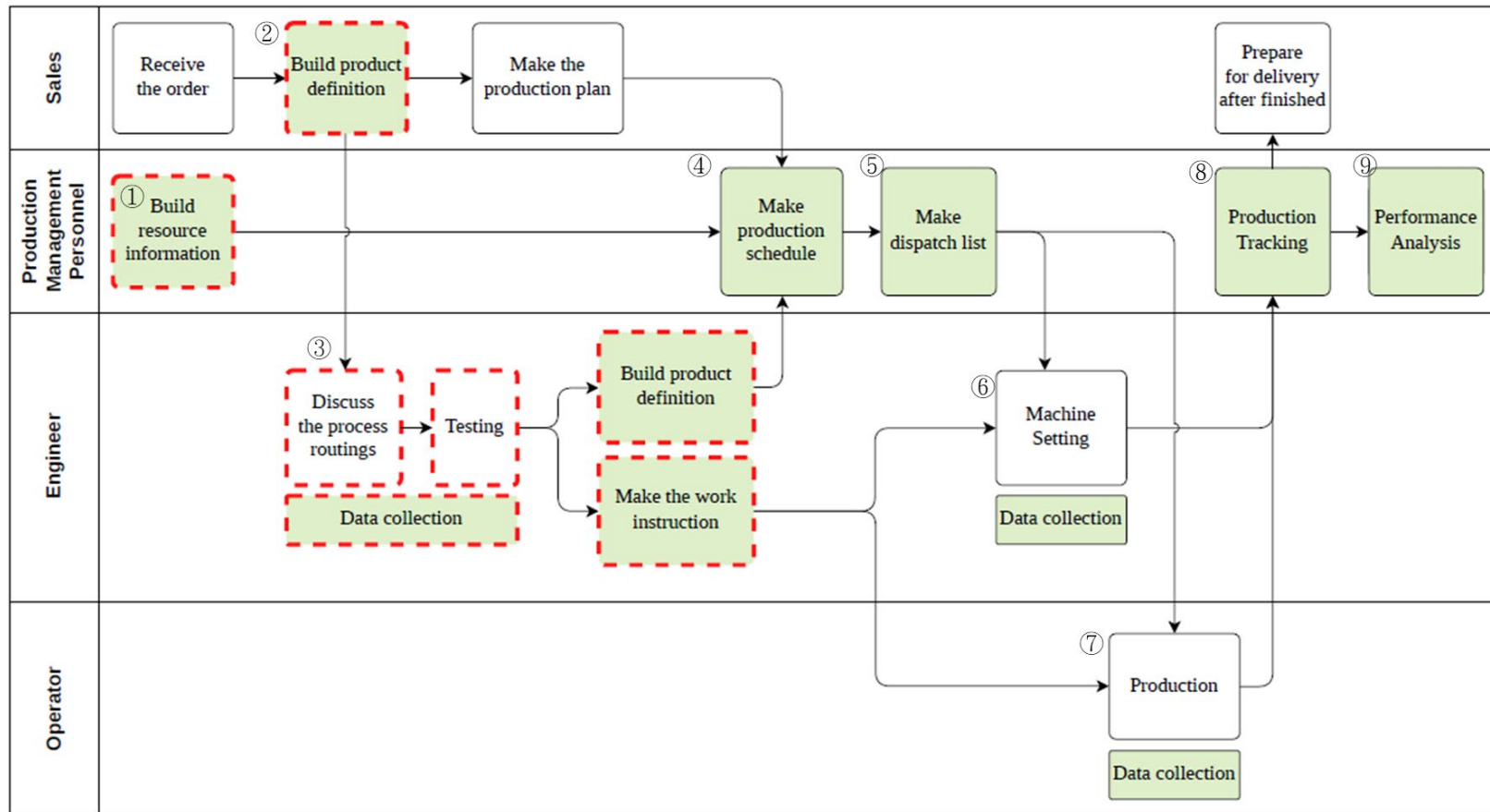


Figure 28 Reengineering Production Process Flow Chart (To-Be)

The steps of reengineering production process are as follows.

To make the reengineering production process specifically, this study takes one of Company Y's products as an example to demonstrate how the reengineering production process works.

1. Firstly, production management personnel should establish resource information. Table 2 presents the partial equipment of Company Y, "machining range" indicates the machining capacity of the equipment. This information is crucial for dispatching. Table 3 presents the partial personnel list of Company Y (names are fictitious), where the crucial aspect is the "capacity" of each individual. It is essential to clearly specify the products or areas of expertise for each laborer, as this information is vital for dispatching. Table 4 presents the Operation List of Company Y.

Table 2 Part of Equipment List of Company Y

Code	Machine	Brand	Model	Controller	Machining Range	Year
L1	Lathe	Takizawa	NEX-108	Fanuc	320mm x 480mm	2013
L2	Lathe	Takizawa	NEX-108	Fanuc	320mm x 480mm	2014
L3	Lathe	Takizawa	NEX-110	Fanuc	400mm x 650mm	2014
L4	Lathe	Takizawa	NEX-110	Fanuc	400mm x 650mm	2018
M1	Milling Machine	Hartford	VMC-1300	Mitsubishi	1300mm x 700mm	2007
M2	Milling Machine	Hartford	MVP-10	Mitsubishi	1000mm x 600mm	2008
M3	Milling Machine	Hartford	MVP-10	Mitsubishi	1000mm x 600mm	2011
M4	Milling Machine	Hartford	MVP-13	Mitsubishi	1300mm x 700mm	2010
M5	Milling Machine	Brother	S-700	Brother	700mm x 400mm	2019

Table 3 Part of Labor List of Company Y

Employee No.	Name	Department	Job Title	Capacity	
				Product	Grade
T10101	Ann	Turning	Senior Engineer	Product A	3
				Product B	5
				Product C	5
T10605	Bill	Turning	Engineer	Product A	1
				Product B	3
				Product C	5
T09801	Jane	Turning	Operator	Product A	5
				Product B	5
				Product C	4
T10904	Wendy	Turning	Operator	Product A	4
				Product B	5
				Product C	4
T11006	Mary	Turning	Operator	Product A	4
				Product B	3
				Product C	3
T11010	Nana	Turning	Operator	Product A	0
				Product B	0
				Product C	1

Table 4 Operation of Company Y on Plex

Operation Code	Operation Type	Inventory Type	Inventory Unit
Y-Cleaning	Production-Std	WIP	pcs
Y-Material	Receive/Inspect	Raw Material	pcs
Y-Milling_1	Production-Std	WIP	pcs
Y-Milling_2	Production-Std	WIP	pcs
Y-Milling_3	Production-Std	WIP	pcs
Y-Milling_4	Production-Std	WIP	pcs
Y-Milling_5	Production-Std	WIP	pcs
Y-Packaging	Production-Std	Finished Goods	pcs
Y-Turning_1	Production-Std	WIP	pcs
Y-Turning_2	Production-Std	WIP	pcs
Y-Turning_3	Production-Std	WIP	pcs
Y-Turning_4	Production-Std	WIP	pcs
Y-Turning_5	Production-Std	WIP	pcs

2. Upon receiving a new order, the sales personnel should establish product definition information and communicate it to the engineering department for discussing process routings. Then, establish a production plan based on the order and convey the plan to production management personnel. Specifically speaking, the production plan here is like due date table. This task typically occurs during the initial production of a new product and only requires updates and maintenance thereafter.

Take product R001 as an example. The product definition information is shown in Table 5. A product, requested by Customer A with the number R0001, is a round plate with five holes in it. Customer A provides the material as depicted in image (a) in Table 5, while the finished good is shown in image (b). The engineer's task is to transform image (a) into image (b) through mechanical processing. The production plan illustrated in Table 6.

Create a product definition that can address the issues raised by sales personnel regarding instances where engineers or production management personnel forget product information. It can prevent bothering customers, thereby averting a decline in customer confidence in the company. If companies continuously ask customers the same questions may lead them to question whether this company manages its operations effectively.

Table 5 Product R0001 Information



Customer	Customer A
Part no.	R0001
Part description	round plate with five hole on it
Material	Stainless steel 304
	 (a)
Product	 (b)






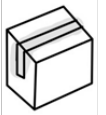
Table 6 Production Plan

Part No.	Order No	Quantity	Due Date	Estimated production started date	Estimated production finished date
R0001	OR230302406	200	2023.04.29	2023.04.22	2023.04.22
	OR230302407	200	2023.04.30	-	2023.04.23
	OR230302408	200	2023.05.01	-	2023.04.24
	OR230302409	200	2023.05.02	-	2023.04.25
	OR230302410	200	2023.05.03	-	2023.04.26
R0002	OR230402011	500	2023.05.06	2023.04.22	2023.04.30
	OR230402013	500	2023.06.03	-	2023.05.08
	OR230402015	500	2023.07.01	-	2023.05.16
	OR230402017	500	2023.08.05	-	2023.05.24
	OR230402019	500	2023.09.02	-	2023.06.04

3. Engineers, upon receiving information on a new product, should develop the product's process routings as per customer requirements and conduct testing. The engineer's goal is to minimize the number of processing steps and processing time, which relies on the engineer's experience and skills. After completing testing, record the process routings in the product definition. It's crucial to document processing time, tool selection, coding, etc., and create comprehensive work instructions to enhance subsequent operational efficiency. This task generally occurs during the initial production of a new product. When the product has been produced multiple times, updating and maintaining work instructions can be done through data collection during each production cycle. The process routing of product R001 illustrated in Table 7.

The processing routing information is a crucial component of the product definition. Establishing work instructions can assist in stabilizing engineer's setting time. Work instructions offer numerous benefits to operators as well. In cases where an operator forgets the next step, they can promptly refer to the work instructions, thereby reducing the occurrence of erroneous or missing steps. This practice can decrease the probability of defective product occurrences and enhance production capacity.

Table 7 Process Routing of Product R0001

Part No.	R0001					
Customer	Customer A					
Operation Name	Material	Turning 1	Turning 2	Milling 1	Cleaning	Packaging
Operation No.	n/a	10	20	30	40	50
Machine Required	n/a	Lathe	Lathe	Milling Machine	Wash Machine	Packaging Machine
Set up time	n/a	2 hrs	1 hrs	2.5 hrs	0.1 hrs	0.1 hrs
Production rate	n/a	30 pcs/ hr	50 pcs/ hr	20 pcs/ hr	150 pcs/ hr	250 pcs/ hr
Graphics						
Supporting Document	Product engineering drawings, Inspection specifications table, Work instructions etc					

4. Upon receiving the production plan, production management personnel should create a production schedule that aligns with the production plan based on the process routings defined by engineers and resource management information. Table 8 present that daily production schedule. The production schedule should encompass the daily tasks, required output (produced) quantities, the engineer responsible for machine setup, designated equipment to be used, and the assigned operator for production, among other relevant details.

Table 8 Daily Production Schedule

Date	Part No.	Operation No.	standard rate (pcs/hr)	Quantity	Machine	Personnel	Setting Engineer
2023.04.22 Mon.	R0001	10	50	400	Lathe 1	Operator B	Engineer A
	R0001	20	30	240	Lathe 2	Operator C	Engineer A
	R0002	10	10	80	Milling 1	Operator D	Engineer F
2023.04.23 Tue.	R0001	10	50	400	Lathe 1	Operator B	N/A
	R0001	20	30	240	Lathe 2	Operator C	N/A
	R0002	10	10	80	Milling 1	Operator D	N/A
2023.04.24 Wed.	R0001	10	50	200	Lathe 1	Operator B	N/A
	R0001	20	30	240	Lathe 2	Operator C	N/A
	R0002	10	10	80	Milling 1	Operator D	N/A
2023.04.25 Thu.	R0001	20	30	240	Lathe 2	Operator C	N/A
	R0002	10	10	80	Milling 1	Operator D	N/A
2023.04.26 Fri.	R0001	20	30	40	Lathe 2	Operator C	N/A
	R0002	10	10	80	Milling 1	Operator D	N/A

5. Once the production schedule is finalized, create a dispatch list to be handed over to the responsible executing personnel (engineers and operators). Table 9 is the dispatch list table, indicating the personnel responsible for each job and the equipment used for production. Each item in the dispatch list table can generate a dispatch list similar to Figure 27.

Table 9 Dispatching List Table

Date	Time	Part No.	Operation No.	Operation	Description	Personel	Machine	Quantity
2023.04.19	14:00	R0001	10	Turning 1	Setting machine	Engineer A	Lathe 1	N/A
2023.04.19	16:00	R0001	20	Turning 2	Setting machine	Engineer A	Lathe 2	N/A
2023.04.22	08:00	R0001	10	Turning 1	Production	Operator B	Lathe 1	400
2023.04.22	08:05	R0001	20	Turning 2	Production	Operator C	Lathe 2	240

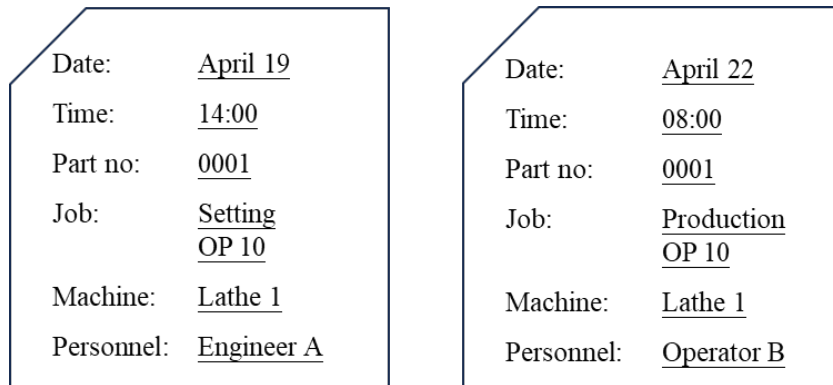


Figure 29 Dispatch List

6. Engineers, upon receiving the dispatch list, should execute the tasks according to the work instructions and collect necessary data during execution. For instance, differences in time spent setting up machines compared to previous tests should be reported to production

management and updating work instructions. Figure 30 is a work instruction sample of product R0001.





R0001 Round Plate Work Instruction OP10 Turning1		
Document No. : _____		Version : 1 Page : 1/1 Date: yyyy. mm. dd
Product Information		
Parts Name : Round Plate	Material (before processing)	Finished (after processing)
Part No: R0001		
Processing Routings		
Material →	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> OP 10 Turning 1 </div> →	OP 20 Turning 2 →
		OP 40 Milling 1 →
		OP 50 Cleaning →
		OP 60 Package
<ul style="list-style-type: none"> ● Setup Time: 2 hrs ● Production Rate : 30 pcs /hr ● Preceding Procedure : <ol style="list-style-type: none"> 1. Confirm the machine status: "Yellow light", production card is marked R0001 2. Cutting oil concentration needs to fall within 10~15%. 3. Confirm that all required tools are ready. (ø2 Hex key, ø3 Hex key, Digital indicator) <div style="display: flex; justify-content: space-around; margin: 10px 0;">   </div> <ol style="list-style-type: none"> 4. If you find any defective materials, please report it to your supervisor or engineer. 5. Work instructions should be followed, and the status of the production line should be paid attention to at all times and recorded in detail. 		
Work instructions (Steps)		
Step	Description	Picture
1		
2		
Defective product (If any of the following situations occur, please report to the engineer immediately)		

Figure 30 Work Instruction Sample

7. Operators, upon receiving the dispatch list, should execute tasks following the work instructions. Data collected during execution includes output quantity, defective quantity, etc., to be reported to production management personnel (who should also supervise), facilitating production tracking.
8. Production management personnel can adjust schedules using production information obtained through production tracking. When production quantities meet the planned targets, this information is relayed to the business department to arrange shipment operations.
9. Production management needs to conduct performance analysis, including analyzing production conditions, production efficiency, personnel efficiency, equipment utilization, etc.

4-5 Summary

This chapter discusses the potential impact on order fulfillment at a machining factory- Company Y, exploring the reasons and the current production process. After identifying potential factors affecting order fulfillment, this study reengineers Company Y's processes according to the guidelines proposed in this study. After I discussed the reengineering production process plan with Company Y's member including boss, sales personnel, engineers, production management personnels, the reengineering production process plan proposed in this study has gained widespread recognition and acceptance from Company Y although Company Y has not implemented this plan yet.

V. Conclusion and Future Research

5-1 Conclusion

The study conducted a reengineering of the production process at the case company using Manufacturing Execution Systems (MES) and the ISA-95 standard as a reference model to bolster the company's order fulfillment capabilities.

First, this study provides the guidelines for process reengineering, encompassing three key steps. These steps enable companies to identify underlying issues related to order fulfillment and shortcomings in their processes. By utilizing a reference model built on MES as the tool for process reengineering and incorporating the activities from the reference model into potential problem areas within the process to address problems, the current processes were reengineered.

The eight activities outlined in the reference model ensure the acquisition and consolidation of necessary information to support various activities throughout the production process. The proposed process reengineering in this study provides an implementation strategy to enhance a company's competitiveness. It underscores the significance of not hastily integrating information software but rather initially adopting process reengineering to refine the production process. Furthermore, selecting MES as a reference model can aid companies in mitigating potential obstacles when considering the implementation of MES software in the future.

5-2 Future Research

This research relied on the Manufacturing Operations Management (MOM) of ISA-95 as the foundation for establishing the reference model. Future research could explore the other three management aspects outlined in ISA-95, namely Maintenance Operations Management, Quality Operations Management, and Inventory Operations Management, as potential research themes. Additionally, this study solely focused on information exchange within the production process, neglecting message transmission between other hierarchical levels. This presents a potential avenue for future investigation. Moreover, this study only considers the company's internal production process and does not consider the impact of the supply chain on order fulfillment, which also provides a new direction for future research.

To sum up, three future research advice are listed below:

1. Explore other management aspects, maintenance, quality and inventory within MOM.
2. Consider information exchange between different hierarchical levels based on ISA-95
3. Evaluate the impact of the supply chain on order fulfillment

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