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Integration of ERP Systems and Production Information Systems: Approaches and Methods

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Abstract— *This paper touches upon the integration of ERP systems as well as production information systems in the context of transitioning from an R&D manufacturing company to an automated factory. The article mainly focuses on implementing a manufacturing execution system (MES) to bridge the gap between planning and control systems and actual production operations. The work considers the approaches and methods used to streamline processes, improve efficiency, and enable data-driven decision-making. Key topics include work order creation, manufacturing process flow modeling, product workflows, electronic procedures, operator training, statistical process control, and modeling audit trail. The case study presented highlights the successful implementation of MES by a company, showcasing the benefits of such integration for improved production management.*

Keywords— *MES, ERP systems, production information systems, manufacturing operations management, decision-making, equipment effectiveness, manual processes, Viralsinh, information technology.*

I. INTRODUCTION

The integration of Enterprise Resource Planning (ERP) systems and manufacturing information systems is a critically important task in the context of modern industrial production. This issue becomes particularly relevant when companies transition from a research and development (R&D) production model to fully automated manufacturing. Under these conditions, the implementation of a Manufacturing Execution System (MES) becomes a key factor in the successful transformation.

MES serves as a bridge between business planning and management systems, such as ERP, and actual manufacturing operations. The primary function of MES is to monitor and document the process of transforming raw materials into finished products in real time. The system collects data from various sources, including equipment, sensors, and operators, providing accurate and up-to-date information on the state of production processes.

Implementing MES enables organizations to make data-driven decisions by providing comprehensive and accurate production information. This enables continuous process improvement and resource optimization. Additionally, MES helps managers determine overall equipment effectiveness (OEE) – an important metric used to monitor production efficiency.

Transitioning from an R&D production model to automated manufacturing presents several challenges related to the integration of various information systems. In particular, it is necessary to ensure seamless data exchange between the ERP system, MES, and other manufacturing systems. This requires not only technical integration but also a revision of business processes and training personnel in new methods of operation.

The aim of this research is to analyze approaches and methods for integrating ERP systems and manufacturing information systems, with a special focus on implementing MES in the context of transitioning to automated manufacturing. The research aims to address the following key questions:

1. What are the main challenges in integrating ERP and MES systems during the transition to automated manufacturing?
2. Which approaches and methods are most effective in addressing these challenges?
3. How does MES implementation impact the efficiency of production processes and management decision-making?

This study is based on the analysis of practical experience in implementing MES in a manufacturing company transitioning from an R&D-oriented production to fully automated manufacturing. It examines specific approaches and methods used to optimize processes, enhance efficiency, and ensure data-driven decision-making.

The results of this research have both theoretical and practical significance. Theoretically, they contribute to a deeper understanding of the processes of integrating information systems in the manufacturing environment. Practically, the identified approaches and methods can be used by other companies facing similar production transformation challenges.

II. THEORETICAL PART

A Manufacturing Execution System (MES) is a software solution designed for monitoring and controlling manufacturing processes within an enterprise. In the context of managing production operations, MES acts as a link between enterprise planning and management systems, such as ERP, and actual production processes. The main function of MES is to monitor and record the conversion of raw materials into finished products in real time.

MES collects data from various sources, including equipment, sensors, and operators, providing accurate and up-to-date information on the state of production processes. This information is critically important for making operational decisions and optimizing production. Unlike ERP systems, which focus on overall enterprise resource planning and management, MES concentrates on direct management of shop-

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floor manufacturing processes. The MES architecture landscape is presented in Figure 1.

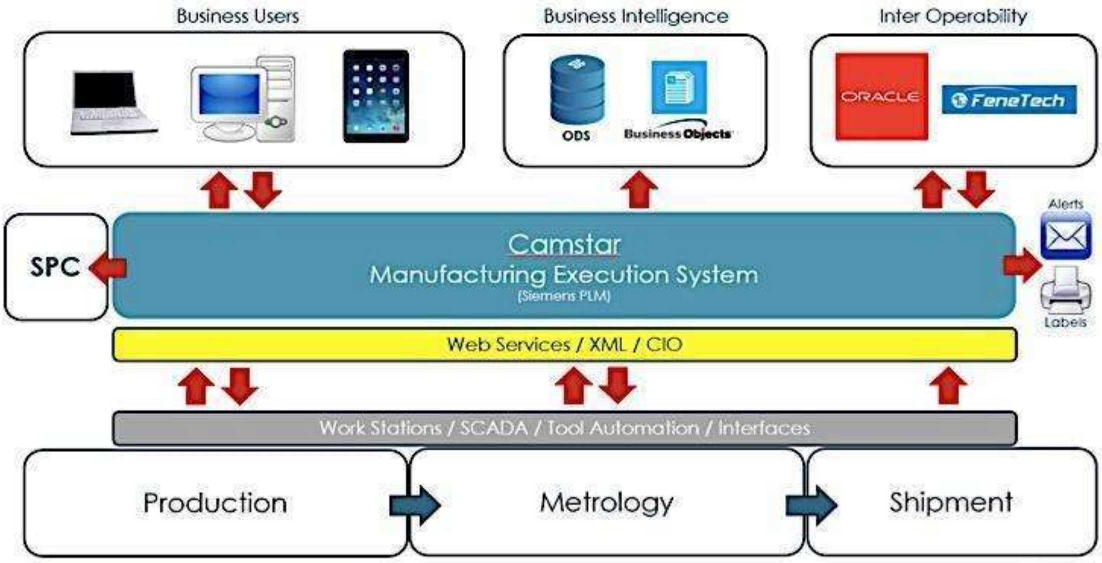

Figure 1. Factory Systems: MES Architecture Landscape[1]

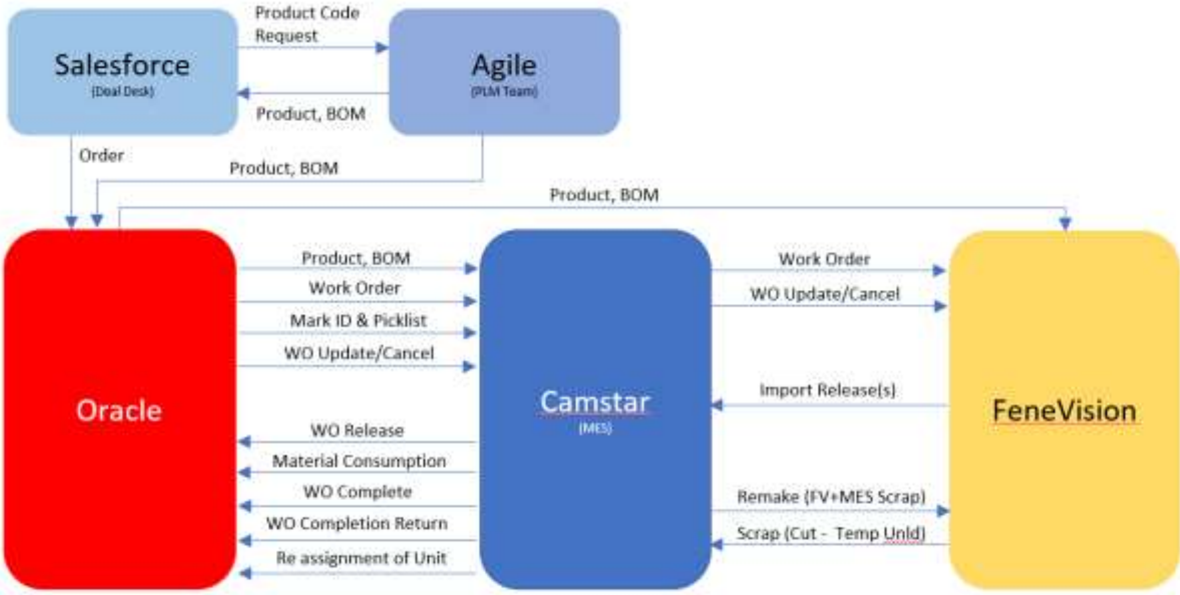

Figure 2. Quote to Cash: Integration Data Flow[2]

It is crucial to understand the legacy system and the operation process of each component, starting from a customer order entered in Salesforce, moving into Oracle ERP (enterprise resource planning), and then flowing into factory systems to transition to MES. In the legacy system, none of the factory systems interact with upstream systems like Oracle or Salesforce and vice versa. The entire process—from order creation to shipment—is done manually. Figure 2 illustrates the integration data flow.

The relationship between MES, ERP, and other enterprise information systems forms a comprehensive manufacturing management architecture. The ERP system provides data on orders, materials, and overall planning, which MES uses for detailed planning and control of production operations. In turn, MES sends real-time information back to ERP about order progress, material consumption, and equipment status. This bidirectional connection ensures the integrity and currency of data across the enterprise's information ecosystem.

[1] Dalibor Berić, Darko Stefanović, Bojan Lalic, Ilija Cosic. The Implementation of ERP and MES Systems as a Support to Industrial Management Systems, June 2018 International Journal of Industrial Engineering and Management 9(2): 77-86
[2] Vladimír Modrák. Integration of MES and ERP. Encyclopedia of Information Science and Technology, Second Edition, 2009

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Key components and functions of MES include:
1. Work Order Creation and Management: MES automates the creation of work orders based on data from the ERP system, optimizing production planning.
2. Production Process Modeling and Configuration: MES allows for detailed modeling of production processes, including defining the sequence of operations, resources, and quality parameters.
3. Workflow Management: The system ensures the control and optimization of workflows, including product routing and managing alternative production paths.
4. Electronic Procedures: MES supports the creation and execution of electronic procedures, ensuring the standardization of manufacturing operations and quality control.
5. Operator Training and Certification: The system integrates personnel competency management functions, ensuring operator qualifications meet production process requirements.
6. Statistical Process Control (SPC): MES includes tools for collecting and analyzing statistical data on product quality and process efficiency.
7. Maintenance Management: The system coordinates the planning and execution of equipment maintenance tasks, integrating these processes into the overall production cycle.
8. Product Tracking and Genealogy: MES provides complete traceability of the production history for each product unit, which is critically important for quality control and regulatory compliance.
9. Production Efficiency Analysis: The system offers tools for calculating and analyzing key performance indicators, including Overall Equipment Effectiveness (OEE).
10. Integration with Automation Systems: MES interacts with SCADA, PLC, and other automation systems, ensuring data collection directly from production equipment.

Implementing MES enables organizations to achieve significant improvements in production efficiency by optimizing resource utilization, reducing downtime, improving product quality, and accelerating responses to changes in production processes. Additionally, MES ensures transparency of manufacturing operations, which is critically important for making informed management decisions and continuously improving processes.

In the context of transitioning from an R&D production model to automated manufacturing, MES plays a key role in ensuring the flexibility and scalability of production processes. The system allows for quick adaptation of production to new requirements while maintaining the high level of control and efficiency characteristic of mass production.

III. Approaches and Methods

As part of the optimization of manufacturing processes and the integration of ERP and MES systems, comprehensive work was conducted to automate the creation of work orders and model production flows. The study identified significant deficiencies in the legacy order management system, where planners manually created orders in the industry software Fenevision, which was not integrated with the Oracle ERP system. This process took over 10 minutes per order and was characterized by a high risk of data entry errors, leading to significant time losses—up to 1.5-2 hours daily depending on the volume of orders.

To address this issue, an automated system integrating Fenevision with MES was developed and implemented. The new system optimizes orders in Fenevision and automatically transfers the identifiers of individual glass units (lite IDs) to MES in a matter of seconds, a task that previously required an additional 20 minutes of manual work by planners each day. This innovation significantly improved the efficiency of the order creation process and minimized the risks associated with human error.

In the context of modeling and configuring the production process, in-depth analytical work was carried out to study the capabilities of the Camstar MES system and existing legacy systems. This allowed the development of a comprehensive model that includes both physical and process components of production.

The physical model covers a wide range of elements, including the definition of the enterprise, factory, organizational structure, employees, roles, resources, and their settings. Special attention was given to modeling resource statuses, defining resource types, their families, and groups. The model also includes components related to carriers, documentation, recipes, settings, and work centers.

The process model, on the other hand, represents the control part of the information system and includes objects such as operations, specifications, product families, material specifications, ERP routes, recipe lists, master recipes, workflows, and process timers.

A key element of optimization was the development of predefined product workflows. Unlike legacy systems, where processes were often not clearly defined, the new approach involves creating detailed process flows from glass cutting to shipping finished products. To achieve this goal, a series of interdisciplinary meetings were held with the participation of business owners, technologists, supervisors, quality teams, equipment teams, and IT teams, allowing for the alignment and optimization of predefined production flows.

The inclusion of various participants was crucial for creating a comprehensive and effective workflow system:
1. Business Owners: Their participation ensured that the developed processes aligned with the overall strategy and goals of the company, and addressed financial aspects and market needs.
2. Technologists: Their expertise was necessary to determine the optimal technological parameters of processes, ensuring their efficiency and compliance with technical requirements.
3. Supervisors: Their practical experience in managing production allowed for the consideration of real-world conditions and constraints on the shop floor, ensuring the realism and applicability of the developed processes.
4. Quality Team: Their involvement guaranteed that all process stages met quality standards and regulatory requirements, and allowed for the integration of quality control procedures at each stage.
5. Equipment Team: Their knowledge of the capabilities and limitations of production equipment was critical for optimizing processes and ensuring their technical feasibility.

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6. IT Team: Their participation ensured the integration of the developed processes with existing information systems and accounted for technical capabilities in process automation.

As part of optimizing manufacturing processes, a workflow system was developed and implemented to represent the sequence of steps necessary for product production. Each product definition is linked to a specific workflow, which outlines the route and processes required for its creation. Workflows were designed considering the order type and the specifics of processing at the production site.

A key task was identifying different types of workflows, modeling them, and configuring them. To facilitate this process and ensure consistency across all departments, numerous data flow diagrams and process documentation were created. As a result, the following workflows were identified, modeled, and configured: standard production (Gen3, Gen4), Bird Friendly, In House LAMI, Buy out LAMI, Filler, Halo evolution research, and Mate Flow.

Each workflow includes numerous elements, such as steps, paths, routes, and sub-flows. Steps define the processing at a specific stage of the workflow and contain a set of instructions, including tasks performed by an employee and events that must occur for processing the container at that stage.

A particularly challenging task was developing the path system, as this process was entirely manual in the legacy system, requiring real-time decision-making. In the new MES system, paths need to be predefined and selected based on specified conditions or instructions.

A path in a workflow determines the direction from one step to another. The system allows for creating alternative paths from any given step, providing flexibility in the production process. Path selectors are used to choose a specific direction.

An innovative aspect of the developed system was the implementation of alternative route mechanisms. In standard situations, containers follow a predefined path, but under special conditions, defined through assertion selectors, the system allows deviation from the standard route. This enables additional or alternative processing, enhancing the system's flexibility in various production scenarios.

Particular attention was paid to rework processes, which are critically important for ensuring product quality. The developed system includes cyclic path mechanisms, allowing a container to be returned to the beginning of the current step for reprocessing if certain parametric requirements are not met.

Rework paths are defined as a sequence of actions necessary to address problems or undesirable outcomes that arise during normal processing. In some cases, business rules may require returning the container to a previous step or even the current step for additional processing. To achieve this, predefined rework paths are configured in the system, allowing operators to effectively manage the process according to specific constraints and quality requirements.

Thus, the developed system of rework path management and alternative routes is a key factor in maintaining the quality and flexibility of manufacturing processes, enabling quick adaptation to various production situations and product quality requirements.

Within the framework of the developed manufacturing process management system, innovative concepts of routes and sub-flows were implemented, significantly enhancing production flexibility and efficiency.

A route in the system represents a sequence of steps connected by paths. A workflow can include multiple routes, one of which is standard. The selection of a specific route (standard or alternative) for a container is determined using path selectors. This allows the system to adapt to various production scenarios, such as rework or the need for additional product processing.

The concept of sub-flows was developed to manage complex manufacturing processes. A sub-flow is an independent workflow that can be linked to a specific step in the main flow. This is particularly useful in cases where the details of processing within one step are too complex to be described within a single specification. Sub-flows can be utilized by multiple workflows, increasing the modularity and reusability of system components. For example, if production is carried out at two physical sites producing similar products, these sites can use different versions of the main workflow but refer to the same sub-flow at a specific stage.

The main component of the developed system is the execution model, which integrates the configuration of the physical and process models. This model tracks the status and history of products and resources at the production site, providing an up-to-date picture of manufacturing activities in real-time. Tracking functions are implemented through the Production Site Portal and include key components such as control, real-time monitoring of work-in-progress (WIP) status, product genealogy, and equipment status monitoring.

To facilitate the execution of manufacturing processes, a system for modeling various entities was developed, including defining customers, suppliers, production calendars, shifts, teams, production and sales orders. Systems for defining priorities, user codes, object groups, notification mechanisms, and user interface variable definitions were also implemented.

Special attention was paid to the development of electronic procedures, which allow for the viewing and tracking of groups of manufacturing tasks. An electronic procedure is a revisable object that allows assigning a set of tasks to a specific specification. An innovative aspect was the inclusion of process computation tasks, allowing the integration of user-defined constants and detailed computational expressions in task definitions.

For optimizing production logistics, a container dispatching system was developed. This system is based on a predefined sequence of actions corresponding to production orders. Dispatching rules established in the model form dispatch lists, which serve as a guide for production site operators when initiating or moving containers. These rules not only display a list of tasks to be completed but also ensure compliance with a specific sequence of work execution.

To set up the dispatching process, definitions in the model were developed and implemented, including dispatching rules, production orders, operations, work centers, and production sites. This allows for precise determination of how and when

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containers will be moved within the production process, ensuring efficiency and adherence to the production plan.

Thus, the developed system represents a comprehensive solution for managing manufacturing processes, providing a high degree of flexibility, efficiency, and control at all stages of production.

IV. Maintenance Management Procedures

Within the comprehensive manufacturing management system, innovative procedures for maintenance management, operator training, and quality control were developed and implemented. These components play a key role in ensuring the efficiency and reliability of manufacturing processes.

Maintenance management procedures encompass a wide range of activities, including settings, calibration, replacement of consumables, software updates, repairs, and preventive maintenance of resources, including carriers. The developed system allows for defining and tracking maintenance requirements based on calendar dates and throughput indicators. The implementation of maintenance requirements occurs during the execution of services at the production site. The system includes preliminary implementation information, the definition of maintenance reasons, throughput requirements, and dates, including periodic ones, as well as the integration of the maintenance class into the resource and management of movement processes.

Special attention was given to developing a system for operator training and certification. This function allows configuring the information model to ensure alignment with the training and certification objectives for operators. The system guarantees that production employees are properly trained and certified to perform specific tasks before their actual execution (Figure 3).

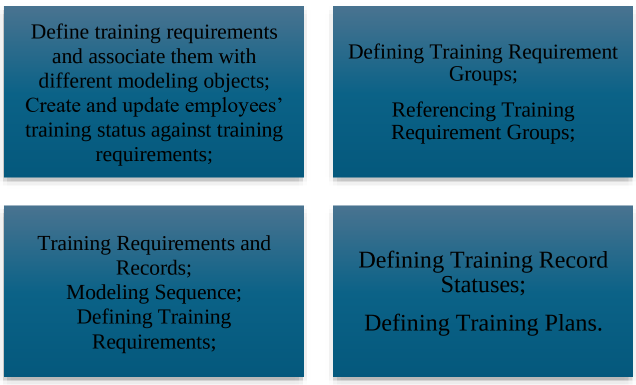

Figure 3. Operator training and certification objectives[3]

An innovative component of the developed system is the statistical process control (SPC) module. This powerful and flexible tool allows manufacturers to address issues before they lead to reduced output or performance. SPC uses quality data as an invaluable source of production information. Specifications in the system ensure that units of work-in-progress (WIP) that do not meet minimum criteria cannot be shipped, which is only the initial stage of quality control. The system enables manufacturers to produce high-quality products without compromising performance.

To ensure transparency and traceability of changes in data modeling, an audit trail system was developed. This system provides a complete history of all changes to modeling objects, helping companies track changes and demonstrate compliance with quality requirements in regulated industries. The audit trail ensures a sequence of audit records resulting from actions with an object, such as creation, modification, or deletion.

The audit trail system provides an accurate record of all changes made to an object during all editing sessions. When a new object is created, the inspection process records all information about it. When an instance is created, the audit trail provides detailed information on which instance attributes were changed, who made the changes, and when they were made. When changes are made to the base object of an edition, the change record is logged in the audit trail for that edition.

The ability to view a pop-up window with the modeling audit trail simplifies access to this information, making it more accessible to users who can quickly obtain the necessary data without delving into complex menus or reports. This also enhances the user experience by providing direct access to the change history.

Using the audit trail page provides a broader overview of the change history and allows for deeper analysis. This can be useful for auditors, data analysts, and other stakeholders who need to understand the context and implications of data changes.

The ability to view the audit trail for a named data object, edition object, and modeling sub-entity allows for precise tracking of changes at various levels and degrees of detail. This provides the flexibility and detail necessary for different user needs and use cases.

Overall, the developed audit trail system is a powerful data management tool that helps ensure the quality and reliability of an organization's information assets, supporting data integrity and version control.

V. Conclusion

As a result of this study, a comprehensive manufacturing process management system integrating ERP and MES systems was developed and implemented. A key element of this work was the creation of detailed process diagrams covering all aspects of the production cycle. These diagrams include expected inputs and outputs, automatic data collection, automatic material consumption, processes for moving, holding, and disposing of products, reasons for delays and rejections, employee authorization, equipment and resource management, location/object, instructions, and triggers for starting operations.

The project development methodology was structured into several key stages. The process begins with the gathering of requirements, which are agreed upon and signed off by business users, forming the basis for further work. This is followed by

[3] The benefits of successful integration between your ERP and MES software, 5 June 2023. Electronic Source https://www.ibitek-group.com/en/2023/06/05/manufacturing-execution-system-software-integration/ Access Date 03.05.2024

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the project implementation stage by the development team based on the approved requirements.

Upon completion of the development, user acceptance testing is conducted in collaboration with business users to ensure that the project results meet the initial requirements and goals. This stage concludes with the signing off of test results by business users, the regional manager, and leaders, confirming the project's quality and readiness for the next phase.

Next, the go-live date is signed off, marking the transition of the project into the active usage phase. After going live, round-the-clock support is provided to ensure uninterrupted operation and prompt resolution of potential issues.

An important aspect of the methodology is the transformation of approved business requirements into technical specifications for the development team. This process ensures the accurate translation of business needs into technical specifications, minimizing the risk of misinterpretation of requirements.

The developed system demonstrates significant advantages in optimizing manufacturing processes. The automation of work order creation and integration of various components of the production system significantly reduced order processing time and minimized the risk of errors. The implementation of predefined workflows and a flexible routing system provided production adaptability to various scenarios, including rework and additional processing.

Special attention was given to aspects of quality and regulatory compliance. The developed audit trail system ensures complete transparency and traceability of all changes in manufacturing processes, which is critically important for regulated industries.

The integration of operator training and certification functions, as well as the implementation of statistical process control, has improved product quality without compromising performance. These innovations contribute to the continuous improvement of manufacturing processes and the maintenance of high-quality standards.

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