MANUFACTURING EXECUTION SYSTEM AS A TOOL FOR PRODUCTION PLANNING AND DAILY MANAGEMENT

Case study perspective

Lappeenranta–Lahti University of Technology LUT

Master`s Programme in Industrial Engineering and Management, Innovation and Logistics

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Johanna Perkola

Examiners: Docent, Associate Professor Jyri Vilko, D.Sc. (Econ.)

Junior Researcher, Alisa Misukka, M.Sc. (Econ.)

ABSTRACT

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Johanna Perkola

Manufacturing execution system as a tool for production planning and daily management: Case study perspective

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Keywords: Manufacturing execution system, MES, production planning, daily management, challenges, solutions

This master's thesis investigates the suitability of manufacturing execution system (MES) as a tool for production planning and daily management when they are currently handled with enterprise resource planning (ERP) system, multiple excel sheets and possible unintegrated systems. The focus of the investigation is solving challenges related to production planning and daily management, not the cost or payback period of the system.

The research includes literature review, and a case study conducted for Finnish manufacturing company. The case study is related to identifying challenges in production planning and daily management and solving them with MES, resulting in preliminary study of available MES solutions suitable for the needs of the case company.

The final result of the research was that the MES was, for the most part, a suitable solution for overcoming the identified challenges. For some challenges, it was found that the solution also required clarifying practical processes and agreeing on common operating methods. For solving challenges related to detail planning, a separate advanced planning and scheduling (APS) system was found to be necessary.

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Tuotantotalous

Johanna Perkola

Tuotannonohjausjärjestelmä tuotannonohjauksen ja päivittäisjohtamisen työkaluna: Näkökulmana tapaustutkimus

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Avainsanat: Tuotannonohjausjärjestelmä, MES, tuotannonsuunnittelu, päivittäisjohtaminen, haasteet, ratkaisut

Tämä diplomityö selvittää tuotannonohjausjärjestelmän (MES) soveltuvuutta tuotannonsuunnittelun ja päivittäisjohtamisen työkaluksi, silloin kun niitä nykyisellään hoidetaan toiminnanohjausjärjestelmän (ERP), useiden excel-taulukoiden ja mahdollisten integroimattomien järjestelmien avulla. Tutkimuksen painopiste oli tuotannonsuunnitteluun ja päivittäisjohtamiseen liittyvien haasteiden ratkaisemisessa, ei järjestelmän kustannuksissa tai takaisinmaksuajassa.

Tutkimus sisältää kirjallisuuskatsauksen ja suomalaiselle teollisuusyritykselle tehdyn tapaustutkimuksen. Tapaustutkimus liittyi tuotannonsuunnittelun ja päivittäisjohtamisen haasteiden tunnistamiseen ja niiden ratkaisemiseen tuotannonohjausjärjestelmän avulla. Tapaustutkimuksen lopputuloksena kohdeyritykselle tehtiin alustava selvitys markkinoilla olevista MES-ratkaisuista, jotka vastaavat kohdeyrityksen tarpeeseen.

Tutkimuksen lopputuloksena voitiin todeta toiminnanohjausjärjestelmän olevan suurimmilta osin soveltuva ratkaisu tunnistettujen haasteiden nujertamiseksi. Muutamien haasteiden osalta ratkaisuun todettiin tarvittavan myös käytännön prosessien selkiyttämistä ja yhteisten pelisääntöjen sopimista. Hienokuormituksen osalta todettiin erillinen tuotannonsuunnittelujärjestelmä tarpeelliseksi tunnistettujen haasteiden ratkaisemiseksi.

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This master's thesis is the final piece of my Innovation & Logistics studies in Industrial Engineering and Management. Past little over three years have been demanding, but at the same time have provided new perspectives and approaches.

Jumping from the world of University of Applied Sciences to University was much more challenging than I anticipated. While writing this master's thesis motivation and perseverance were about to run out on several occasions, but thankfully the nearest friends and colleagues encouraged to continue.

Most of all I want to express my gratitude to my husband, who has listened my frustrated complaints and still encouraged me to move forward with writing little by little. Working full time and simultaneously studying for the past seven and half years have finally reached the endpoint.

Huittinen, 6th June 2025

Johanna Perkola

ABBREVIATIONS

APS	Advanced Planning and Scheduling
BOM	Bill of Materials
DM	Daily Management
ERP	Enterprise Resource Planning
FIMECC	Finnish Metals and Engineering Competence Cluster
HSEQ	Health, Safety, Environment, Quality
KPIs	Key Performance Indicators
MANU	Future Digital Manufacturing Technologies and Systems
MES	Manufacturing Execution System
MESA	Manufacturing Enterprise Solutions Association
MOM	Manufacturing Operations Management
OEE	Overall Equipment Efficiency
OEM	Original Equipment Manufacturer
WIP	Work-In-Progress
WMS	Warehouse Management System

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1 Introduction

Traditional production management can be seen as a black box; out of touch from production, unable to meet the changing, complex needs. The black box needs to be made transparent; a manufacturing execution system (MES) was born out of this need. It is a workshop oriented management system that holds the key to information integration and operation optimization. Its purpose is to collect real time data from the production floor and maintain the two-way communication between the production floor and the operative employees. (Fei, 2010.)

1.1 Research background

The employer of the author commissioned this master's thesis from the case company's need to conduct a study for acquiring a manufacturing execution system; what kind of advantages could be achieved in production planning and daily management compared to the current state of doing things? The research is structured around this topic in such a way that it is easy for not only the case company but also other manufacturing companies to benefit from the findings made in this research.

1.2 Research objective, questions, and limitations

The objective of this research is to identify challenges related to production planning and daily management in manufacturing companies and to examine how MES can solve these challenges through identified advantages. From the point of view of the case company the aim of the research is firstly to identify the challenges of the case company's production planning and daily management. Secondly, examine how these challenges could be overcome by using MES. And lastly, provide a preliminary study for the case company on the MES options available on the market in relation to their identified needs.

The research questions for this master's thesis are

1. *What kind of challenges related to production planning and daily management can be identified in a manufacturing company?*
2. *How can a manufacturing execution system help solve these challenges?*
3. *How does the available MES solutions meet the case company's needs?*

The research is limited by the case study conducted for the case company. As a starting point the research focuses on situations where a company uses some kind of enterprise resource planning (ERP) system. Other possible solution options for solving the identified problems are not considered beside MES, because the case company specifically wanted to explore whether MES alone could solve the challenges, from software point-of-view. The case study is limited as shown in Figure 1.

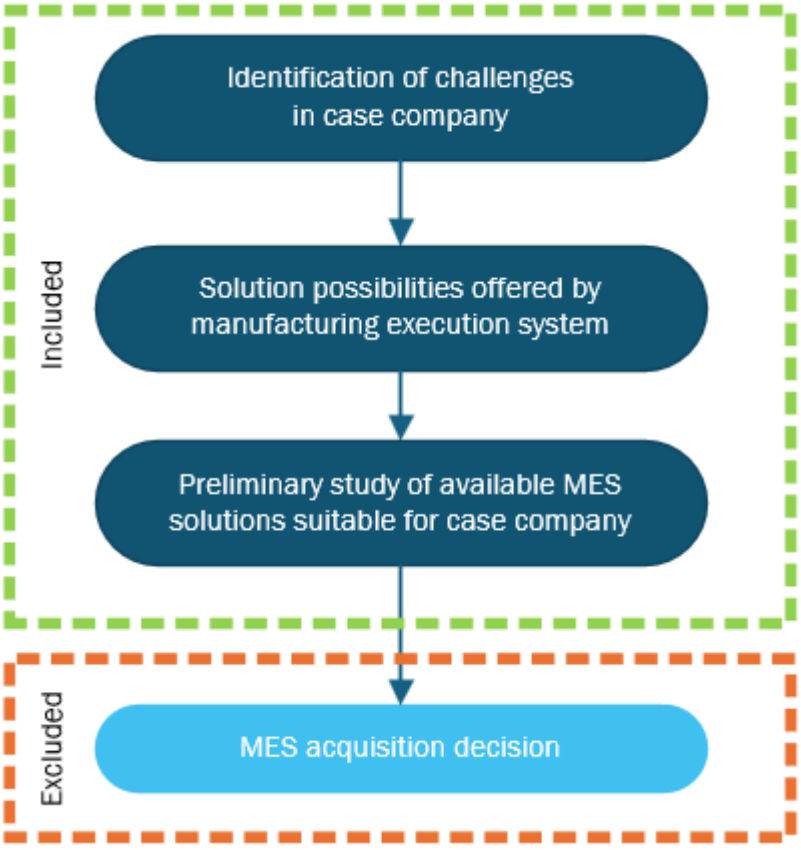


Figure 1. Research limitations for the case study

1.3 Research methods

The methods behind information gathering for this research consist of literature review, internal and external interviews & meetings, and internal workshops. A case study was constructed from the interviews, meetings and workshops. All notes and recordings related to interviews, meetings and workshops are kept by the author, due to their confidential content.

A literature review is a research method in which existing knowledge is identified, evaluated, interpreted, and combined. Its purpose is to summarize relevant, existing knowledge and draw conclusions based on pre-established research question, ultimately forming an overall picture. In thesis's, it is typical for sources to be multidisciplinary, varying in time period or text type, or they may be based on a single way of thinking, in which case only one or two sources are referenced. (Vilkka, 2023.) The literature review was made mostly with peer-reviewed articles, but also includes data gathered from digital publications and e-books, e-magazine databases and relevant web pages.

Research focusing on examining one specific case is called a case study. It is commonly used in industry research. Case study is also known as action research, and it differs from traditional research by trying to find practical solutions instead of generalizing knowledge. (Duesbery & Twyman, 2021.) Case study approach was a clear choice for this master's thesis due to having practical objective of making a preliminary study for the case company.

Interviews can be categorised in structured, semi-structured and unstructured. Structed interview includes predefined questions, that are asked from all respondents. It is typically used when comparable answers are wanted as result. Semi-structed interview consist of close- and open-ended questions. Unstructured interview has various definitions, and terms such as informal conversational interview and nonstandardized interview are used to describe it. Most likely there are no questions or answers predetermined, only the top-level topic is defined, and the conversation can vary greatly among respondents. (Zhang & Wildemuth, 2017.) The interviews were conducted as semi-structured or unstructured. Answers were manually processed instead of using software, due to the limited amount of them.

1.4 Structure of the research

Figure 2. presents the research structure with an input-output model. The inputs illustrate the content needed for each chapter and the outputs illustrate the chapters contribution for the research.

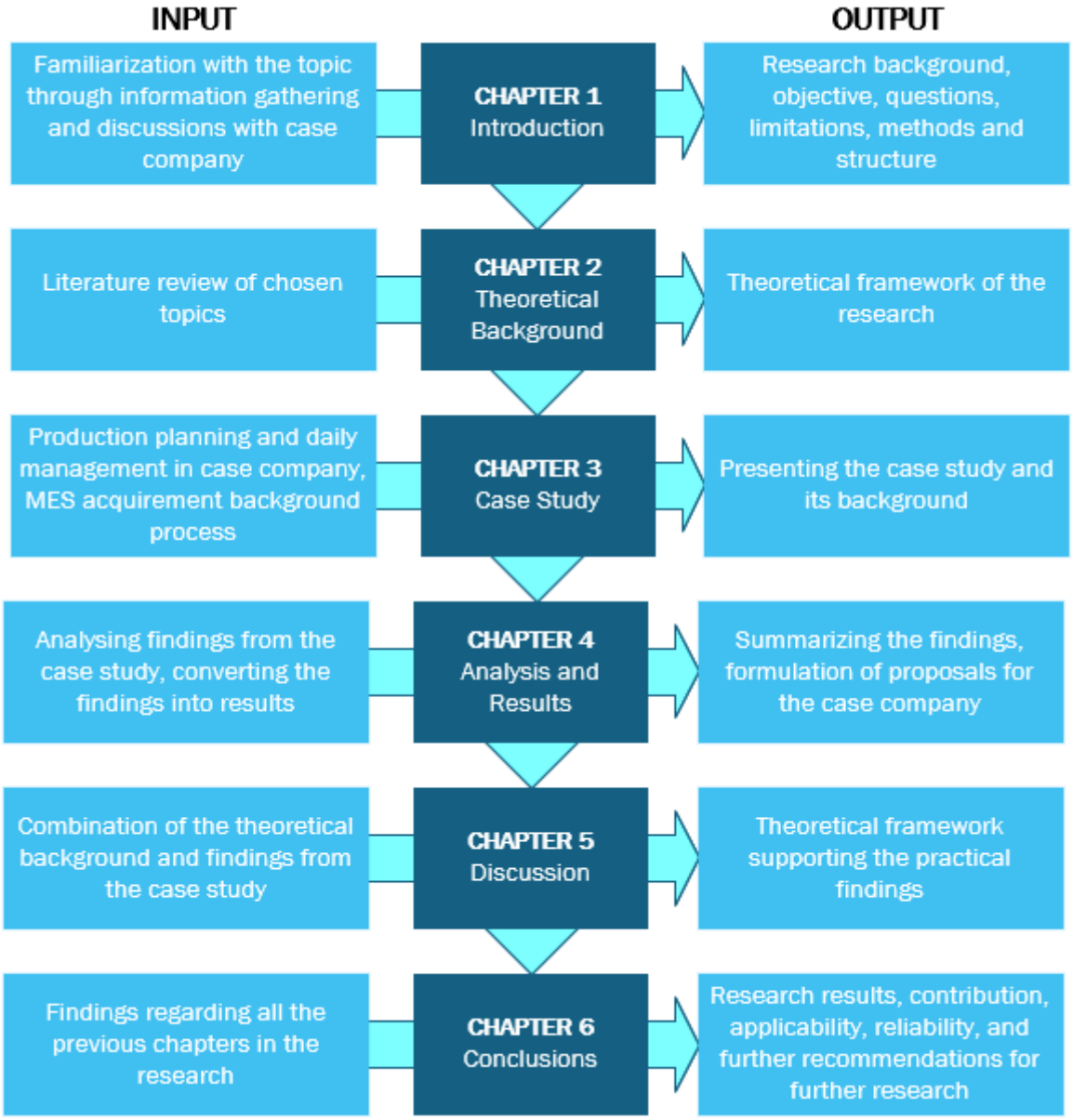


Figure 2. Research structure

2 Theoretical Background

This chapter includes the theoretical background of this master's thesis. The chapter gives insight of manufacturing execution system and the principles behind production planning and daily management. In addition, the chapter introduces DIMECC's, formerly known as FIMECC (Finnish Metals and Engineering Competence Cluster), Future Digital Manufacturing Technologies and Systems (MANU) programs LeanMES sub-project.

2.1 Manufacturing execution system according to ISA-95 standard

ISA-95, an international set of standards based on Purdue Reference Model, aims to integrate logistics systems with manufacturing control systems. It was developed by the International Society of Automation for exchanging information with abstract model between enterprise manufacturing control and business functions. The set of standards has eight parts containing models and terminology that can be used when analysing a manufacturing company. The abstract model, knows as the ISA-95 model, has five levels as show in Figure 3. (International Society of Automation, n.d.)

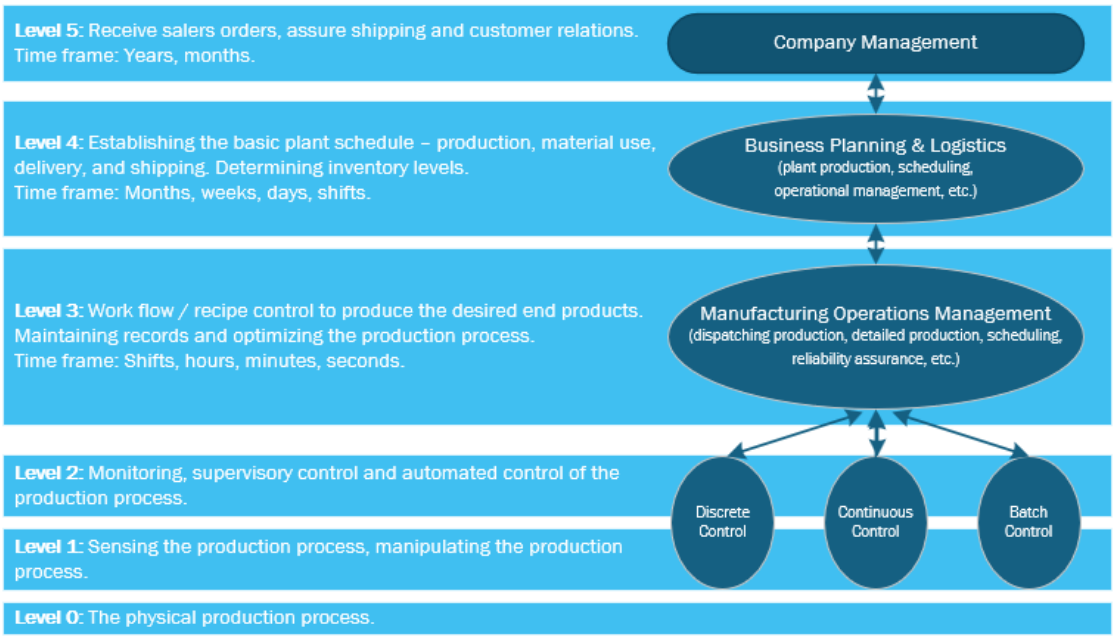


Figure 3. ISA-95 model (International Society of Automation, n.d.)

The interface between levels three and four is the main focus of the ISA-95 standard. Level three describes operational activities and systems managing manufacturing operations, such as manufacturing execution system (MES), warehouse management system (WMS) and scheduling & planning system (APS). The combining term for them is manufacturing operations management (MOM). Level four describes the enterprise level business operations, such as enterprise resource planning system (ERP). (International Society of Automation, n.d.) Figure 4. shows the crucial information exchange between these two levels from the point of view of ERP and MES systems.

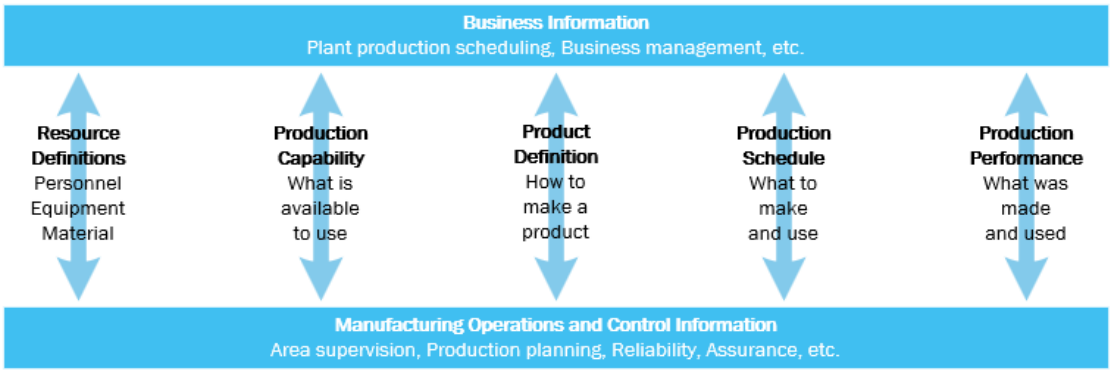
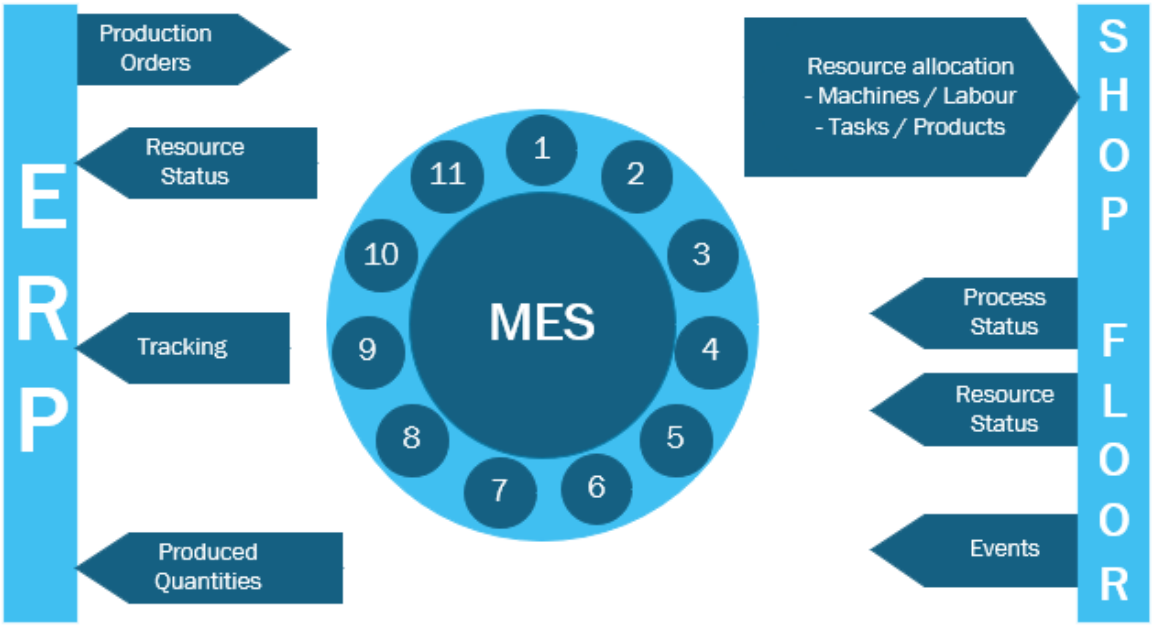


Figure 4. Information exchange between ERP and MES system (EMQ Technologies Inc., 2023)

2.2 Manufacturing execution system according to literature

MES was developed in the mid-1990s to address the inadequacy of the ERP system in real-time operational management of production floor (Shojaeinasab et al., 2022). Historically MES was defined by software editors based on customer expectations or capacities of the editors' tools. First formal definition of MES was published in 1997 by Manufacturing Enterprise Solutions Association (MESA) International, established in 1992. According to it MES optimizes production from order launch to finished goods using current data. It guides, initiates, responds to, and reports on plant activities in real-time, enhancing operations by reducing non-value adding activities. This improves asset returns, on-time delivery, inventory turns, gross margin, and cash flow. MES provides critical production information across the enterprise and supply chain through bidirectional communication. MESA International simultaneously identified eleven principal functions for MES, which can be seen in Figure 5. (Saenz de Ugarte et al., 2009; Tabim et al., 2024.)



1. Operations/Detail Scheduling	Sequencing and timing activities for optimized plant performance on finite capacities of the resources
2. Process Management	Directing the flow of work in the plant based on planned and actual production activities
3. Document Control	Managing and distributing information on products, processess, designs or orders, as well as gathering certification statements of work and conditions
4. Data Collection / Acquisition	Monitoring, gathering and organising data about the processess, materials and operations from people, machines or controls
5. Labour Management	Tracking and directing the use of personnel during a shift based on qualifications, work patterns and business needs
6. Quality Management	Recording, tracking and analysing product and process characteristics against engineering ideals
7. Dispatching Production Units	Giving the command to send materials or orders to certain parts of the plant to begin a process or a step
8. Maintenance Management	Planning and executing appropriate activities to keep equipment and other capital assets in the plant performing to goal
9. Product Tracking & Genealogy	Monitoring the progress of units, batches or lots of output to create a full history of the product
10. Performance Analysis	Comparing measured results in the plant with goals and metrics set by the corporation, customers or regulatory bodies
11. Resource Allocation and Status	Guiding what people, machines, tools and materials should do, and tracking what they are currently doing or have just done

Figure 5. MES functionalities (Saenz de Ugarte et al., 2009)

According to Shojaeinasab et al. (2022) MES main functionalities include data acquisition and abstraction, operation detail scheduling, resource allocation & control, production dispatch, product quality control, and equipment maintenance. Implementing MES improves key performance indicators (KPIs) such as lead time, cost, quality, transparency, and efficiency. MES provides online information on machine breakdowns, and delays, aiding ERP layer in responding better to disturbances and disruptive events.

Industry 4.0 continues where digitalization left off, aiming to provide visibility, transparency, predictive capacity and adaptability (Mantravadi, Srai & Møller, 2023). It aims for intelligent, flexible, efficient, and predictive production, starting with data integration from MES and other sources. Analysing this data enhances product design, planning, production stages, and equipment maintenance. (Shojaeinasab et al., 2022.)

For Industry 4.0 MES has the key role, as it is a crucial software for the factories of the future (Mantravadi & Møller, 2019). MES is in the middle of smart supply chains, from where it coordinates horizontal integrations and helps integrating vertical business processes to ERP system. It schedules production tasks with real-time capacity considering the current situation of products. In case of failure, MES can use algorithms to optimize production rescheduling and maintenance plans. It collects and stores big data gathered from manufacturing processes and converts them into real time KPIs. (Shojaeinasab et al., 2022.)

Beric et al. (2018) conducted a market research in the Republic of Serbia, that included thirty-four companies, mostly from automotive industry. The results of the study showed that the main benefits of MES, compared to only having ERP system, are better information flow, more efficient production planning and quality assurance. The benefits able reacting faster to changes, improve productivity and competitiveness, and provide a strategic advantage. Only a small minority of the respondents believed that MES would not benefit the company. In industrial companies the benefits recognized were better employee participation and training process, reduction of paper documentation, real-time data exchange with ERP system, better structure for production planning and production capacity, simpler monitoring of production, and better system for implementing maintenance.

Around 1995 MESA International sponsored an industry survey, that mapped out the benefits offered by MES from the field. The respondents agreed that MES reduces manufacturing cycle time by av. of 45%, lead time by av. of 27%, and WIP levels by av. of

24%. MES also reduces or eliminates paperwork between shifts by av. of 61%, the possibility of losing paperwork or blueprints by av. of 56%, and time used for data entries by av. of 75%. In addition, MES reduces defects by av. of 18% by improving production capacity and empowers the employees. The benefits transferred to financial level; payback period for the respondents MES acquisitions were between six months and two years, on average fourteen months. (Hakanson, 1996.; Younus et al., 2010.)

Similar to the benefits found by MESA International, Govindaraju & Putra (2016) listed eight achievable goals for MES implementation. Four of them were possible reductions; reducing work time used to maintain manufacturing documents, reducing WIP levels by reducing lead times, reducing the amount of missing production lots, and reducing operational costs. In addition, MES could improve the quality of data used for assessing products and processes, give visibility and transparency for the whole production chain, enhance decision-making process by providing real-time data and optimize the entire supply chain with better control of the workflow.

MES provides interfaces to production floor with ERP systems. This connection improves the process transparency and visibility due to enabling a real-time access of information for all stakeholders – creating an opportunity for detection and correction of deviations rapidly. Production floor employees have more time for production tasks instead of filling in paper forms. Real-time data collected from production floor by MES makes it possible to monitor availability, quality and performance. By converting this data into KPIs, bottlenecks and potential instabilities can be foreseen, and corrective actions can be made before they realize. (Dutta et al., 2022.)

2.3 DIMECC MANU program - LeanMES

DIMECC MANU program was conducted between late 2012 and the end of 2016. It included thirty-five companies and six research institutes. The program was divided into six separate sub-projects, as seen in Figure 6., all related to digitalization. (Syrjälä, 2017.) The goal of LeanMES was to digitalize factory floor by delivering solutions of how to make real-time digital information flow visible at all levels – adding competitiveness, agility and productivity by digitalizing the management of manufacturing operations (DIMECC, 2016).

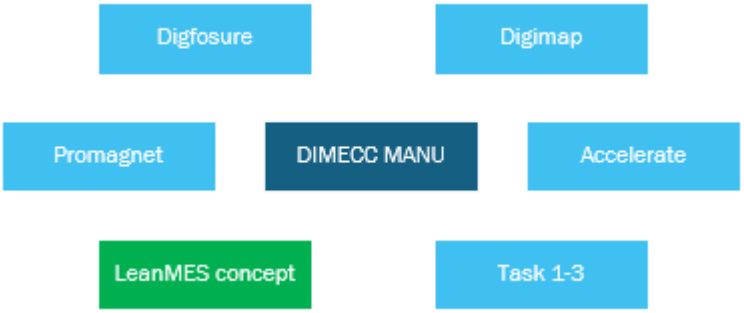


Figure 6. DIMECC MANU program (DIMECC, 2016)

According to Eurostat in 2013 manufacturing sector employed thirty million people and generated almost 1,6 billion euros of added value, showing its importance for Europe. Companies were both forced and encouraged to reduce their productions ecological footprint by EU and international regulations, but at the same time companies were pushed to produce tailored products on demand at low cost, and simultaneously they needed to cope and benefit from demand fluctuations, limited batch sizes, ageing workforce and manufacturing globally, which created multiple challenges. To meet these challenges, companies needed to adjust production capacity, reschedule orders and balance workforce. Productivity and efficiency needed to be increased and non-value adding processes generating costs needed to be decreased. Total efficiency could be increased by decreasing time spent on non-value adding functions such as manual typing, information searching, rewriting and printing work orders in paper. Key element for manufacturing competitiveness was said to be dynamic response to emerging events, whereas responsiveness would be the next strategic goal along quality and costs. (DIMECC, 2016.)

Traditionally operation management was said to be conducted with stand-alone systems that don't communicate within surrounding environment. This led to cost increasement of non-value adding functions and slowed down processes that added value. The LeanMES project aimed to strengthen lean thinking in all operation levels; a novel MES concept for better observation, planning and reacting in dynamic and distributed production environment, that supports human operators. The solutions and concepts of LeanMES project (Figure 7.) were detected to decrease throughput time and operational costs, enabled visibility in supply chain, enhanced quality, introduced new products and in general, modernized manufacturing. (DIMECC, 2016.)

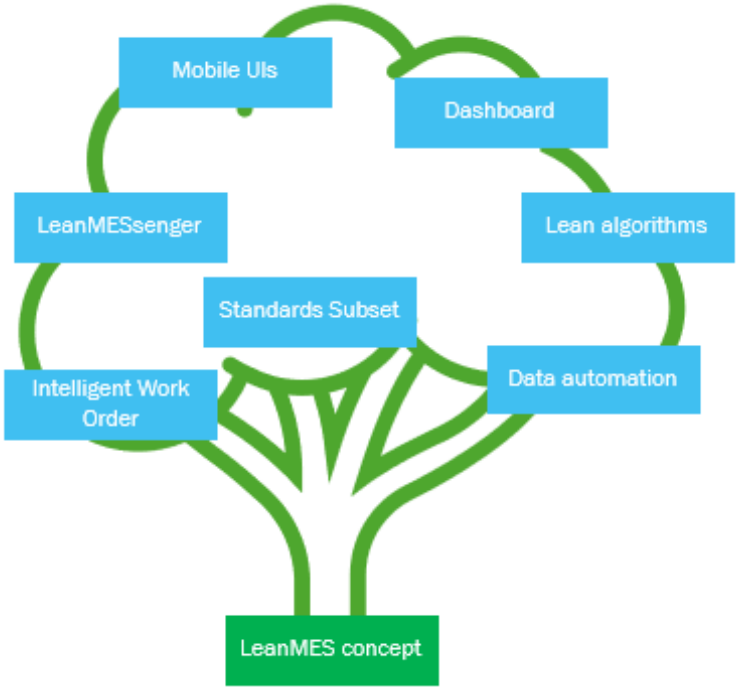


Figure 7. Common LeanMES concept and concrete solution blocks (DIMECC, 2016)

The LeanMES project delivered a prototype of new-age MOM concept, suitable for dynamically changing environment, that would support human operators by being extendable, scalable and lean. The concept was based on modularity, open interfaces and OPC UA & ISA-95 standards, and it was verified by simulations. The main aim for the concept was to support the daily activities of production managers, planners, and shop-floor operators based on lean philosophy - right information in right place at right time in right format. (DIMECC, 2016.)

2.4 Finnish manufacturing companies current state and challenges

As a part of the LeanMES project Järvenpää et al. (2015) conducted research related to Finnish manufacturing companies. The research focused on current state and challenges of production planning & control among twenty-five participant companies. The research states that on factory floor level the planning and control of production is not supported with proper IT-tools; scheduling, dispatching and operations control are done with tools such as Microsoft Excel that are not integrated with the company's other IT-systems nor support rapid reacting to disturbances and changes, while MES and APS system are rarely used.

Rapidly changing demands for customized products, unpredictable and fluctuating demand, and small batch sizes characterize today's manufacturing environment. Due to these characteristics manufacturing systems need to adapt flexibly and competitively, targeting continuous improvement and minimizing non-value adding functions. Information needs to be collected, managed and served effectively from manufacturing operations in order to support daily tasks in all levels of production. The information is also needed for making rapid decisions and changes. Constant monitoring of production status and quality is important in case of failure, deviation or other problem. Information transparency reduces the waste of time by eliminating the need to search information from multiple places or multiple times. MES can provide this information and in addition it allows measuring success, can improve work performance and enables production processes related continuous improvement. (Järvenpää et al., 2015.)

The participant companies represented both original equipment manufacturer (OEM) and sub-contracting companies sized smaller or bigger than 250 employees. Three types of personnel were interviewed: production managers, production workers and main users of production planning and execution systems. Only production managers were questioned with all eighty standardized open-ended questions, others were only asked relevant questions related to their work. The questions were from four categories: 1) Production planning and control practices and tools 2) Shop floor level production control 3) Key performance indicators 4) Lean practices and their implementation status. The gathered answers were analysed and results organized in six categories. (Järvenpää et al., 2015.)

Two companies out of the twenty-five participant companies had some sort of MES, in addition one company was preparing for MES pilot at the time of the interviews. All three companies were OEM’s bigger than 250 employees. All of the interviewed companies planned, scheduled and controlled their production with ERP system, excel sheets and paper & pen. The latter were needed because ERP system does not support planning with capacity restrictions and therefore pose challenges in scheduling. Using excel sheets for detailed production scheduling involves personnel risk; they are typically highly personified and updating can be usually done only by one or two employees. Majority of participant companies were still using paper work orders. (Järvenpää et al., 2015.)

Disturbances on the production floor were caused by rush orders, machine breakdowns, unavailability of components and supplier quality defects. All of these created the need to

re-schedule orders, and that can be laborious process with ERP system and excel sheets, because all phases need to be re-scheduled separately, and it needs to be done for both ERP and excel due to lack of integration. Because of the manual workload, such situations are often handled only on the production floor, leaving no data for later phases of production planning. Therefore, companies are missing the consequences of actual realized processes and causes. (Järvenpää et al., 2015.)

Detail scheduling was mostly done on day's accuracy due to ERP system restrictions. Getting greater accuracy was desired from many of the participants. Workload planning was mostly done with average loads that were not based on reliable history data of actual loads. For example, assembly time for basic systems was known accurately but once these were customized and more options added; accurate assembly time was very difficult to estimate and depended on worker performing the task. This causes challenges in labour intensive production. Production plan was commonly lacking the proactive machine maintenance scheduling which led to not taking capacity reductions into account. (Järvenpää et al., 2015.)

The need of increasing transparency was recognized by all participant companies. Real time information was not received on time; change information on order delays were typically received once it was too late to react efficiently. Order related information was mostly received by email or phone, requiring manual handling to ERP system, that can lead to errors, or may never reach the correct people. Generally, information flow was in state where different departments worked with different information. For example, production could be producing with wrong timing due to not having the real demand information from sales. Most companies wanted to enhance information transparency and accessibility by getting rid of separated systems and instead start to use one system with common rules throughout the organisation. Getting the overall picture of production was considered challenging, because real time order status was not available and among production floor, the workers did not know what other workstations are doing or what their workstation is supposed to do next. Visualization of information and improved transparency would give the workers better image of their own role and its meaning on company level. (Järvenpää et al., 2015.)

KPIs commonly used by the participant companies were reliability of deliveries, quality faults, productivity, efficiency and utilization rate. Quality faults were mostly based on customer claims and deviations on internal quality. More than half of the larger companies used visualization of KPIs in production floor by displays or notice boards. Challenge related

to KPIs was the reporting cycle; due to the exhausting reporting process, KPIs were commonly updated once a month. Data needed to be collected from various sources, and it could take one or two days. Because the KPIs lack behind, they cannot be utilized to support daily actions of planning, control and management. (Järvenpää et al., 2015.)

Majority of participant companies though that defected products should not advance from workstation to workstation. In practice this was not implemented; errors were corrected at the final workstation. Due to this kind of operating method quality issues are hidden and eliminating them is not supported. Recording of quality problems was reported to be problematic – some workers did not report through official channels; some companies did not even have an official channel. Quality data was commonly gathered to separate system alongside ERP, and it was gathered manually or automatically, dividing into even more systems. (Järvenpää et al., 2015.)

2.5 Production planning and daily management

Planning has an important role in supply chain, in which many decisions need to be done and executed every minute. With planning the best alternatives of future activities can be identified and selected. The art of planning can be divided into phases. The first phase is recognizing the decision problem and analysing it. Once analysing is done, objectives need to be defined. Thirdly the future development is predicted, then feasible activities are identified and evaluated, before making the selection of solutions. (Fleischmann, Meyer & Wagner 2015, 71.)

Planning horizon needs to be defined before making any plans, because plans are always restricted in time. Classically planning is made in three different time-levels: long-term, mid-term and short-term. Long-term planning includes the strategic decisions, that affect the supply chain for years to come. Typically, they are decisions related to the supply chains design and structure. Mid-term planning defines the main features of regular activities for horizon of six to twenty-four months, including the quantities and times of flows and resources in the supply chain at a rough level. Short-term planning defines activities in detail, creating instructions for immediate execution and control. Horizon varies from few days to few months. Even though short-term planning is constrained by the long- and mid-term planning decisions, it is an important factor in supply chain: it requires the highest level of

detail and accuracy. Short-term planning effects the supply chain performance directly, because it includes decisions affecting lead times, production delays, and customer service, among other strategic issues. (Fleischmann, Meyer & Wagner 2015, 72.) Figure 8. introduces supply chain planning matrix, that shows the typical tasks related to production planning and daily management.

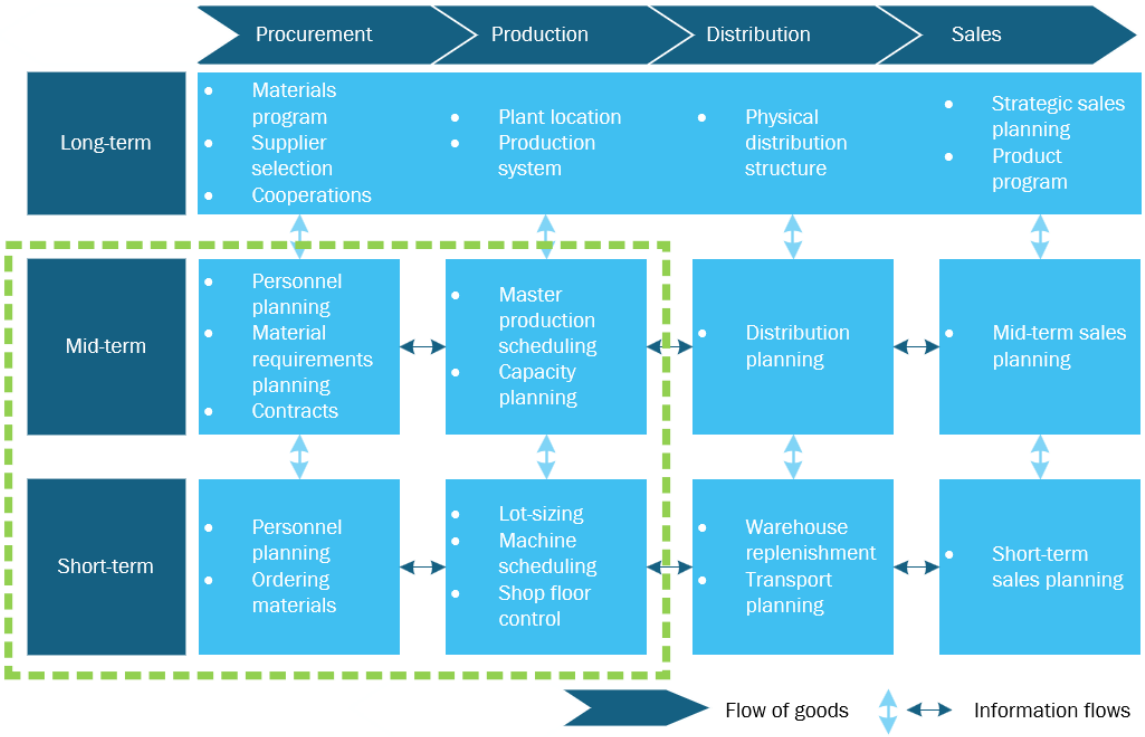


Figure 8. Supply chain planning matrix (Fleischmann, Meyer & Wagner 2015, 77)

Production planning and control is the core action of production program. It ensures that operations can proceed smoothly according to schedule with minimum costs. This is done by making sure materials are available for assembly at the right time, in the right place with the right quantity. Production planning requires dynamic nature and a fluid state; when circumstances change, the plan must adapt accordingly. The functions related to production planning and control are illustrated in Figure 9. Those functions can be divided into three phases: preplanning, planning and control. Preplanning phase includes product design & specification, process design and plant layout. Planning phase consist of capacity, aggregate, material, enterprise resource & tools planning, operation sequences, scheduling and loading. Control phase includes dispatching, expediting, production follow-up, data collection & interpretation, progress reporting, and replanning & modification. (Kiran, 2019.)

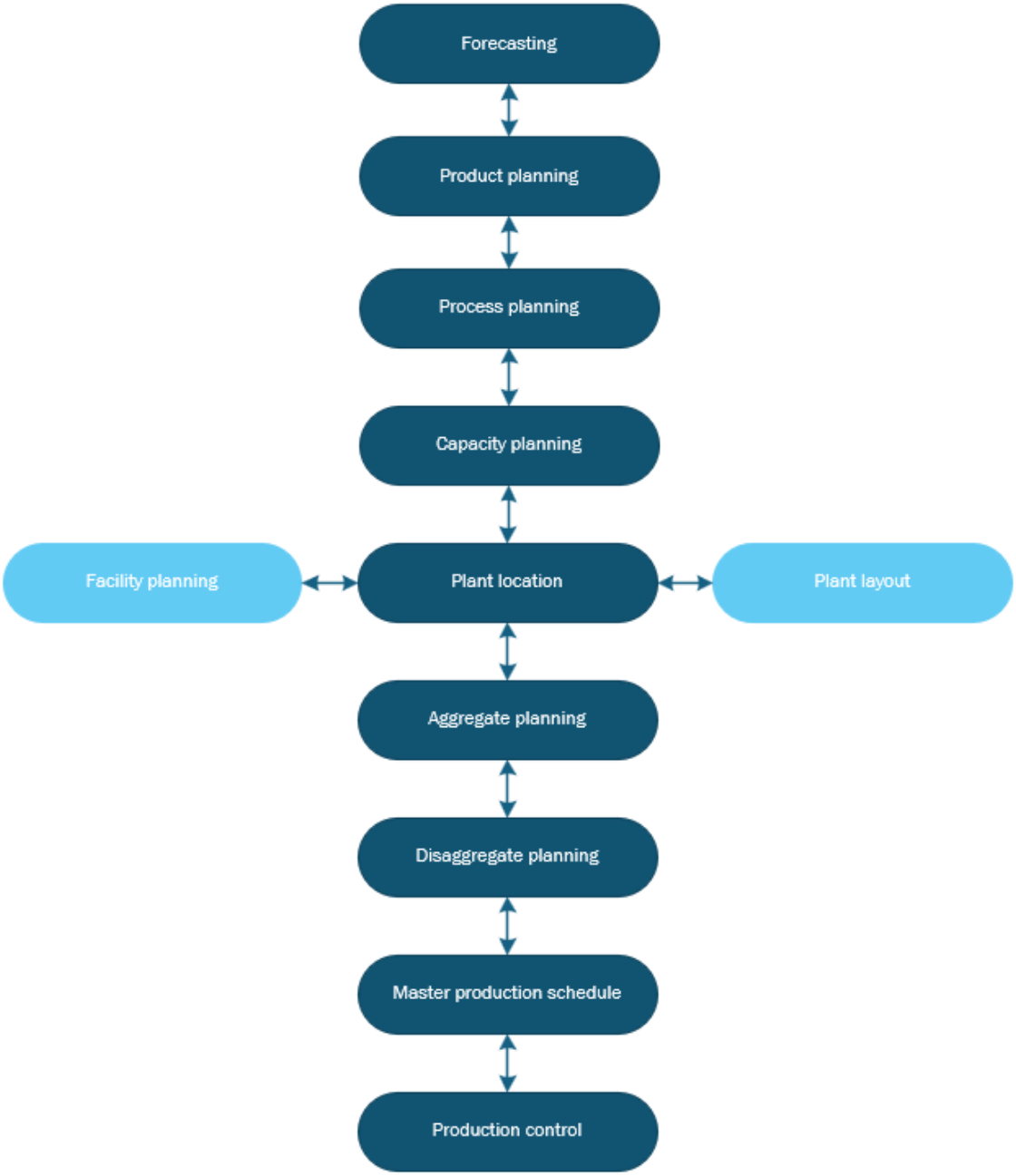


Figure 9. Functions of production planning and control (Kiran, 2019)

Figure 9. illustrated the functions of production planning and control from department point-of-view. The basic functions of individual phases are product planning, forecast planning, process planning, equipment planning, materials planning, and production planning. Production planning includes tasks such as machine loading, operations scheduling, and task sequencing. Forecast planning contains quantity and demand pattern forecasts. (Kiran, 2019.) The other basic functions are not relevant for this master's thesis, due to them not being part of production planning and daily management in the case company.

Production can’t always achieve everything according to plan, due to innumerable factors causing deviations. Typically, these factors are related to material shortage, breakdowns, demand changes, rush orders, employee absence, and lack of communication & coordination. Production control is the function for managing these situations in advance or as they occur, in a way that prevents them happening again later in the future. The aim is to take the necessary corrective measures to match planned and actual production. Production control gives instructions and provides necessary tasks for production floor, ensures that all necessary tools, materials and workforce are available at the right time, monitors that the output quantity and quality are within specifications, and does all previously mentioned with optimal cost. (Kiran, 2019.) *Author’s note: Production control equals to daily management.*

Daily management (DM) is part of Lean philosophy. Some consider it as a critical part of Lean success and sustainability, others ignore it completely, most likely due to it not having a clear definition. DM has been defined as series of efficiently carried out routine activities. (Nicholas, 2023.) DM has twofold purpose: process stability maintenance and retaining past improvement gains (Nicholas 2018, 545). With the help of DM production floor employees can understand their impact in the supply chain and understand the importance of measuring and controlling their daily tasks. Improvement, accountability, tracking and control are emphasised instead of daily readiness. (Moran, 1991.) Commonly recognized parts of DM are KPI boards, self-directed teams, problem solving in groups, and involvement & coaching of the leader (Nicholas, 2023).

From different perspective DM can also mean a short daily meeting held in the production floor by production supervisor. The meeting aims to discuss the events of the previous day, adjust to surprises, plan the current day's work, and finally return to work when the workday has been well planned. (Lean Thinking Oy, n.d.) DMs purpose is not to monitor the actions of the employees, be a channel that distributes daily tasks, reports immediate actions nor being a channel for reporting KPIs. DM is the best way to maintain, enable and develop operations and to provide a context for actively supporting people's continuous learning. It can also create the conditions for the entire organization to constantly observe and identify bottlenecks in the implementation of standard work and its potential challenges. DM can be used to ensure that the measures defined by the organization focus on eliminating essential waste and that the related measures produce results and improve the performance of core processes. (Eskolin, 2018.)

3 Case Study

This chapter introduces the case company; what is the current situation of production planning and daily management, what are the identified challenges related to them, and how production planning and daily management are desired to be developed for the future. The chapter also describes the preliminary study made of available MES solutions suitable for the case company.

3.1 Case company

The case company for this master's thesis is Vexve Oy. Vexve Oy is owned by DevCo Partners Oy, and it is a part of Vexve, formerly known as Vexve Armatury Group (DevCo, 2024). Vexve has factories in Finland, Czech Republic, Denmark, German and China (Vexve Oy, n.d.). This master's thesis focuses only on the Finnish business unit Heavy Valves, that is situated in Sastamala. The author of the master's thesis has worked there since 2014.

The Heavy Valves business unit consist of two factories, known as factory 1 (later T1) and factory 2 (later T2). The product portfolio includes different kinds of ball valves in size range DN150 to DN500, and butterfly valves in size range DN300 to DN1600. Figure 10. introduces the product range of Vexve Finland visually.

Figure 10 Vexve Oy product range (Vexve Ball Valves presentation, n.d.)

3.2 Production planning and daily management in case company

The current state description of production planning is written mostly from the authors point of view – the author worked as a production planner between September 2018 to late 2023 and currently works closely together with production planners and occasionally fills in during the holidays. The production planners participated in the making of the process description for their factories and were interviewed for the challenges they recognize in their daily work, as was the production supervisor in T1. The desired state description is based on interviews and workshops.

3.2.1 Current state description

Heavy valves unit traditionally has had one permanent production planner and a summer trainee for each factory. In history, summer has been the high season for the company. In recent years the trend has slowly changed and nowadays the high season can start from as early as February and end as late as November – the fluctuation is high. Therefore, T1 currently has one permanent and one part-time production planner. T1 also has a production supervisor, who is responsible for daily management, and who works closely with the production planners and occasionally fills in if needed. T2 has one permanent production planner who handles the daily management of the production.

The currently used ERP system has been in use as long as the author has worked in the company. Some bigger improvements, for example a simpler work queue view for production floor, have been made along the years. Recently made improvements, mostly in the other Finnish business unit Light Valves, have been related to implementation of existing features. The use of excels has remained fairly steady since 2018; the amount has not changed much, but improvements have been done.

From system point of view production planning is currently made with ERP system and various excels. The ERP system has functionalities for sales, financials, engineering, purchasing, inventory, dispatch and manufacturing. From Figure 11. can be seen how the ERP system is utilized by each functionality.

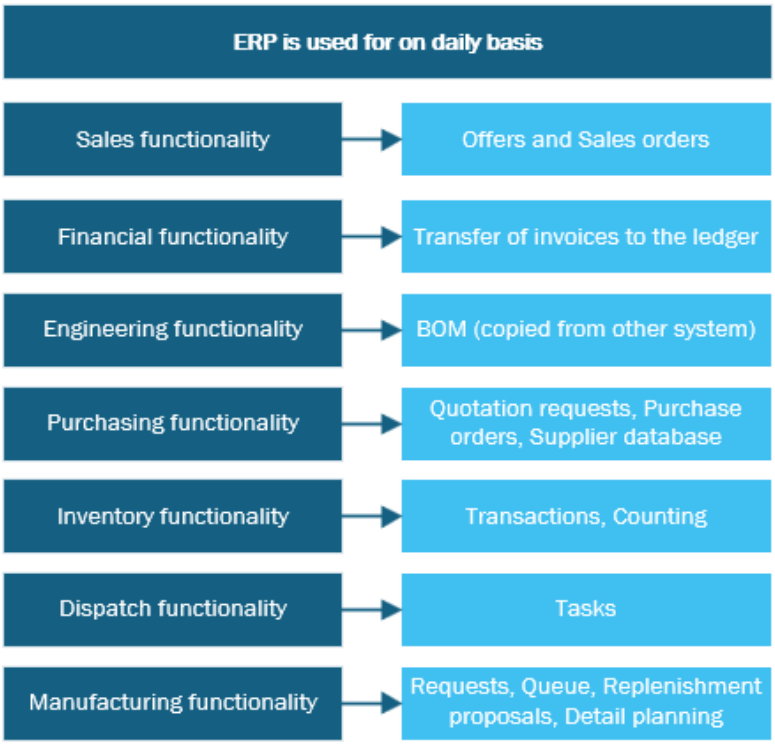


Figure 11. ERP system utilization by functionality

Production planning uses the sales, inventory and manufacturing functionalities on daily basis, but it also needs the access to engineering, purchasing and dispatch for certain actions. So only financials functionality is not used by production planners. Figure 12. shows the main reasons for production planners for using each of these functionalities.

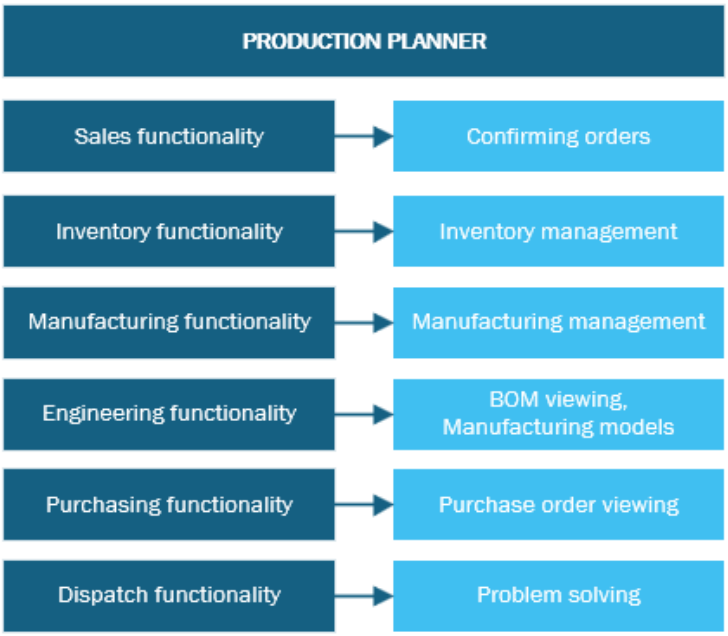


Figure 12. ERP system utilization by functionality by production planner

Figure 13. demonstrates the variety of the work done by the production planners, which includes various daily and irregular operations in addition to the production planning. In addition to those, the production planners usually have other assigned responsibilities, such as product cost accounting. Figure 13. and the explanations given in the following paragraphs describe the production planning basic process while in reality the process includes manufacturing tasks that are already ongoing, previously assigned or loaded.

Figure 13. Production planner responsibilities and production planning process descriptions

From Figure 13. can be noticed that the production planning differs slightly between T1 and T2. In both factories the starting point is the long-term production plan for stock basic models, also known as the forecast, because it is mostly made for sourcing purposes. Data is gathered from the ERP system to an excel, in which the data is processed, and finally the finished plan is either manually or by uploading copied to the ERP system. Next step is opening manufacturing tasks for basic models and work-in-progress (WIP) items according to min-max inventory levels, naturally taking the order backlog into account. After this, in T1 the tasks are assigned to production, whereas in T2 they are only loaded. At this point it should be pointed out, that T1 makes nearly 80 percent of the valves made in the Heavy Valves business unit.

In T1 the tasks are assigned because it is then easier to see the entirety of the production. The majority of sold products are stock items in T1. Therefore, the inventory levels need to be maintained and also the production lot sizes. Usually there are tasks open that go 1) straight to orders 2) in some relation to orders and inventory 3) straight to inventory. In some cases, T1 does use loaded tasks – for example if there is a reason to reserve material or if there is an uncertainty of manufacturing a product. Loaded tasks are not visible for the production floor. It is important for the production planners to be able to see the overall situation of different workstations, and because of this all relevant tasks are assigned – if a task is only loaded, it can be ignored. Once the tasks are all opened and assigned, the production planner does the detail planning. After it is made, they confirm that the production timeline and materials are sufficient; if not, they do the detailed planning as many times as necessary. This is very time consuming and manual, even though it is made in the ERP system, usually with excel assistant. After the detailed planning is done, the production planners will maintain the production plan through change management until it is time for start from the beginning. A worklist is a copy of the ERP systems work queues send to the production floor by email every Friday for the week to come.

In T2 the loaded tasks go through detail planning, which is only done for key / bottleneck workstations. Majority of opened manufacturing tasks are related to orders and take up the capacity and materials even for months if the order backlog is good - in T2 the average production batch lead time is approximately six weeks. Because of this only tasks related to sold products are assigned for a specific time window, the rest of them and the tasks for

inventory remain loaded until they become relevant. This helps keeping the work queue view neat, even though a worklist is still sent to the production floor every Friday by email.

From production planning point-of-view the daily management of production includes monitoring of implementation and following up on special manufacturing tasks. The monitoring of implementation is not possible in real time with the ERP system because the starting point is not registered, and most workstations only log 100 % completed tasks into the system. This means you can't see from a work queue what task is under production and how much of it is already done – you need to inquire this from the worker. The following up on special manufacturing tasks means sometimes running around the production searching for workers to ensure they have all the up-to-date information related to it or making sure they have received the correct dimensional drawing, or they have the correct material, or it might be printing paper notifications to pallets, or finding misplaced items.

In addition to the daily management of production done by production planners, the production supervisor in T1 has other responsibilities, such as capacity planning, updating information monitor slides, Lean related production walks, foreman responsibilities, dispatch tracking, and twice a week short DM meeting in front of the information board and monitor. At the other factory, T2, most of these are handled by the production planner, excluding foreman responsibilities, that are under the production & sourcing manager.

Figure 14. describes how the production floor operates after the worklist is received. The description was based on one-on-one interviews of ten production floor employees from four different departments in March 2025, who were asked simply to explain what they do after they receive the worklist, when nothing is in progress. This process description does not include all events that are performed at the workstations, as there are many differences between workstations and, in some workstations, also between the employees.

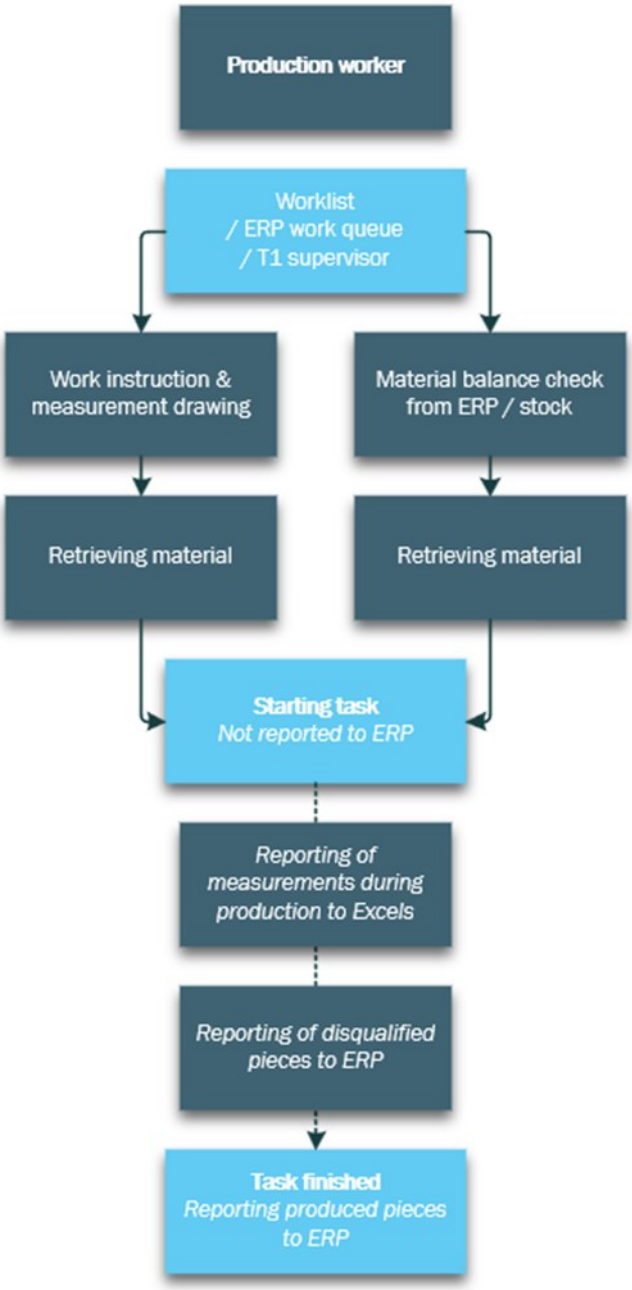


Figure 14. Production worker point-of-view process

3.2.2 Identified challenges

For identifying challenges, all three production planners and the T1 production supervisor were interviewed using unstructured one-on-one interview in March 2025. The interviews were opened with the question "What kind of challenges related to production planning and daily management of production can you identify at the production floor level?" In addition, the production floor employees were asked if they could name any challenges from their point-of-view, when they were interviewed on how the production floor operates after the worklist is received. From the collected data ten main themes were recognized. From each theme one or two challenges were identified, and those challenges were given questions to think about the suitable solution.

Change management

Based on the interview's changes are not always communicated clearly or on-time to the production floor, and it is partly up to the employees to notice the changes. The change management process has not been described and therefore there are many different approaches.

The production supervisor clearly informs changes related to production lot sizes, but there is no clear information about work order changes; these remains to be observed by the workers themselves. – Interviewee A

Urgent information is sometimes communicated poorly; information is transmitted via email, which can easily be missed while working. – Interviewee F

How to ensure that production planner or production supervisor communicates the changes once they are made? How to manage sudden changing situations?

Detail planning

All three production planners agreed detail planning being time-consuming operation; in the current ERP system detail planning could only be done for one workstation at a time. This requires strong knowledge of how the production operates and how items are related. For some items there is an option for doing detail planning throughout task chain, but it can easily disrupt more than it is beneficial.

Detail planning requires so much manual work, that it is easily neglected in haste. – Interviewee L

How to ensure all workstations are organized in a way that enables the production running smoothly without unnecessary delays? How to keep the detail planning updated with minimum time consumption?

Deviation management

The current ERP system does not support deviation management; there is no tool available for the production floor to notify urgent or non-urgent deviations detected at workstations. Due to the lack of process, the notification can be done by calling, emailing, messaging or leaving a note among the items in question. Urgent deviations are usually handled immediately, but non-urgent deviations can easily be forgotten, which can cause problems later on when items are needed.

If there is an urgent deviation that requires a quality representative; they will be asked to attend and the matter will be solved; if the deviation is non-urgent, then the matter most likely will not be solved as a priority. – Interviewee J

How to ensure all non-urgent deviations are disclosed and will be processed? How to make sure all deviations are recorded accordingly?

Information flow

The information flow is a three-way problem; production planning to production floor ⇔ production floor to production planning ⇔ between T1 and T2. Production planning might not always remember to inform the production floor on-time; in some cases, the information might have been given too early for the production floor, and it has been forgotten. The production floor might forget to inform production planning if other operative department has been informed of the matter. The factories manufacture items to each other and with poor change management the information of delays, for example, might not be shared.

The flow of information is not transparent. – Interviewee B

Information flow between factories can be poor; sometimes products arrive with no information on what to do with them or when they are needed back. – Interviewee E

How to ensure all relevant employees have received the information? How to ensure that the information is available in a timely manner, not too early nor too late?

Production reporting

Reporting finished tasks varies by workstation and employee. Some report after a specific amount is done, some after the shift and some when the whole task is finished. This leads to missing or incorrect registrations to the ERP system. Other problem type is having multiple tasks open for an item that is made regularly; it is possible to report the second phase of task to be done, even if the first phase is not. This can lead to problems with inventory levels. Production floor is not able to correct possible reporting errors, if they notice one has been made; they need to notify the production planners or production supervisor.

False production reporting can cause unnecessary haste in production. – Interviewee K

Reporting is done based on mutual agreement between workstation employees. – Interviewee I

How to ensure that employees log the correct manufacturing task correctly?

Quality gate

Reporting measures during production is known as quality gate. It contains workstation specific excel sheets. The challenges with the quality gate are production floor related, filling out the dimensions to the excels, and operative, keeping the desired dimensions up to date in the excels. In some workstation measuring is done automatically by a machine for every produced piece and in some manually by sampling. This information is not saved without filling the quality gate. From operative point of view the problem is getting the real-time information of revision change and updating it manually to the excel sheets.

The quality gate is filled out based on the instructions given, even if it is uncertain whether anyone needs the information there. – Interviewee B

The quality gate is not actively filled because the machine automatically measures all pieces and notifies if it detects a deviation from the dimensions of the first piece. – Interviewee H

Failure to fill in the quality gate is not seen as a major omission; in the measuring room, a more accurate measurement is performed by sampling with a machine. – Interviewee F

How to ensure all relevant employees fill out the required dimensions with required sampling without constant monitoring? How to identify the registrar?

Traceability

The manufacturing of valves is done under the pressure equipment directive (PED) 2014/68/EU. Due to it, the heat numbers for specific materials used for valves need to record and the manufacturer needs to be able to trace these materials back to specific valve/valves. The current ERP system doesn't support collecting the heat numbers and therefore it is not possible to allocate them with the produced items; this is done in excel sheets (T1) or by paper (T2). In the beginning of the production chain the heat number is typically written in the pallet tag the material is in. Once the material reaches a state where it is given a stamp number, the excel sheets / papers come along. Sometimes this can lead to incorrect or even missing heat numbers. The situation is not irreversible, but it may cause hours of unnecessary work.

Traceability process has been identified inadequate, because it includes the possibility of error. – Interviewee M

How to ensure that the correct heat number goes through production chain?

Transparency

The production chain can't be said to be transparent for anyone, even for those with longer tenure or more experience. For example, sales or customer service do not have any other option than inquire from production planning in what production phase valves for specific order are. Even for production planning it is needed to have an excel sheet for order book, that includes the information of what production phase each valve is in. This is updated manually with information gathered from ERP system. There are no real-time KPIs, stock levels or capacity levels available. Sometimes information is withheld between departments for too long, resulting to unwanted situations.

The lack of transparency causes "unnecessary" inquiries from other departments, that are time consuming to answer. – Interviewee N

The production situation is not transparent; if a product waiting to be packaged is not in stock, you have to ask around the factory about its status. – Interviewee C&D

How to ensure that production has visibility throughout the chain? How to make the whole supply chain transparent inside the company?

Unnecessary work

During the interviews few operation methods were questioned and some of them were labelled as unnecessary work. Most frequently mentioned were the worklist and means of reaching out production or operative employees. As previously stated, the worklist is done and send every Friday for production floor, even though it mostly includes the same information that is available in ERP system. Making of it takes time between half an hour up to four hours, if the work queues are not in order in ERP system (and are not put in order while doing the worklist). The most commonly used method of reaching out different employees around the factories are by calling or by going to the workstation / office to find them face-to-face. Especially the latter causes running around the production floor, which is not the most efficient way.

Running around the factory in search of someone is ineffective communication method. – Interviewee N

The worklist and the practices around it are poor. – Interviewee J

How to ensure all related employees are aware of specific detailed information related to manufacturing tasks? How to ensure the work queue in ERP-system is up to date? How to ensure the production employees do not run around the factory looking for someone?

Work that remains to be done

Lastly from the interviews a category "work that remains to be done" was identified as a challenge for production planning and daily management. The production planners and the production supervisor have their hands full on daily tasks, yet some critical tasks should be done for the future development possibilities. These are tasks such as tracking the production time and updating basic information, such as weight, to ERP system master data. In order to have other systems along the ERP system, data needs to correct. The current ERP system does not support collecting these kinds of data by the workstation employee.

Incorrect production times distort production throughput. – Interviewee K

How to collect data alongside manufacturing, without extra work?

In the interview with the production floor employees, they were also inquired, if there was anything they would like to change in the current operating methods? Everyone gave one answer. Three out of ten answered that they wouldn't change anything. According to them, all information needed for doing the assigned tasks was sufficiently available. Three out of

ten pointed out that the ERP system and the worklist should have identical information and both should be up to date all times. Three out of ten pointed out that the production floor should only see manufacturing tasks that have no obstacles. One out of the ten didn't immediately come up with an answer but eventually pointed out that the production workload should be more even throughout the year, meaning there should be better planning for the long term.

3.2.3 Desired future state

Less non-value adding activities. More value adding activities instead of running around the factory making sure things are done accordingly.

Better change management and overall communication to production floor without manual functions. Availability of right information in right place at right time in right format.

Efficient information flow between all parties. Relevant information is made available for all parties once the information has been received and is readily available whenever needed.

More accurate and real-time reporting and information from production floor with minimum effort. The work queue view for production floor to be simpler and only include relevant tasks; will significantly reduce the possibility of misreporting (wrong task) or failure to report (can't start a new one). The work queue view will actively show what task is currently in production for specific workstation and when it is estimated to be ready. Also reporting of task obstacles made transparent.

Collecting accurate data from production without effort. Tracking actual production times and other relevant information. Possibility to have real-time KPIs.

Getting rid of excel sheets connected to other excel sheets. Corporate level goal to reduce the use of excel sheets. Gathering data with more efficient way.

Generating a deviation log. One database where all types of deviations can be recorded with the information of what has been made or needs to be done.

Quality gate as a task phase. Measurement during production is part of the task, not a separate function.

3.3 Preliminary study of available MES solutions suitable for case company

This master's thesis was initiated due to the previously described challenges in production planning and daily management of production - the challenges were recognized long before conducting the interviews, but the interviews created a scientific basis for them. The challenges themselves have been identified as being partly due to the inflexibility of the current ERP system and partly to its inadequate features in relation to practical actions. However, it should also be noted that the operating methods in practice do not necessarily support the ERP system's functionalities. The initial idea for this master's thesis was to research MES solutions, but for the case study also APS solutions were offered by the suppliers, due to them noticing it would be the solution for some of the identified challenges.

The whole process related to finding the suitable MES solution for ERP system in Vexve Oy has been described in Figure 15. The assessments have been done from the point-of-view of operative production employees. The project team consisted of ten members: four production planners, two production supervisors, two business unit directors, a HSEQ manager, and a production & sourcing manager. Four members were from Light Valves business unit. The author served as the project team leader and tried to remain neutral, focusing only on guiding the team towards its goals.

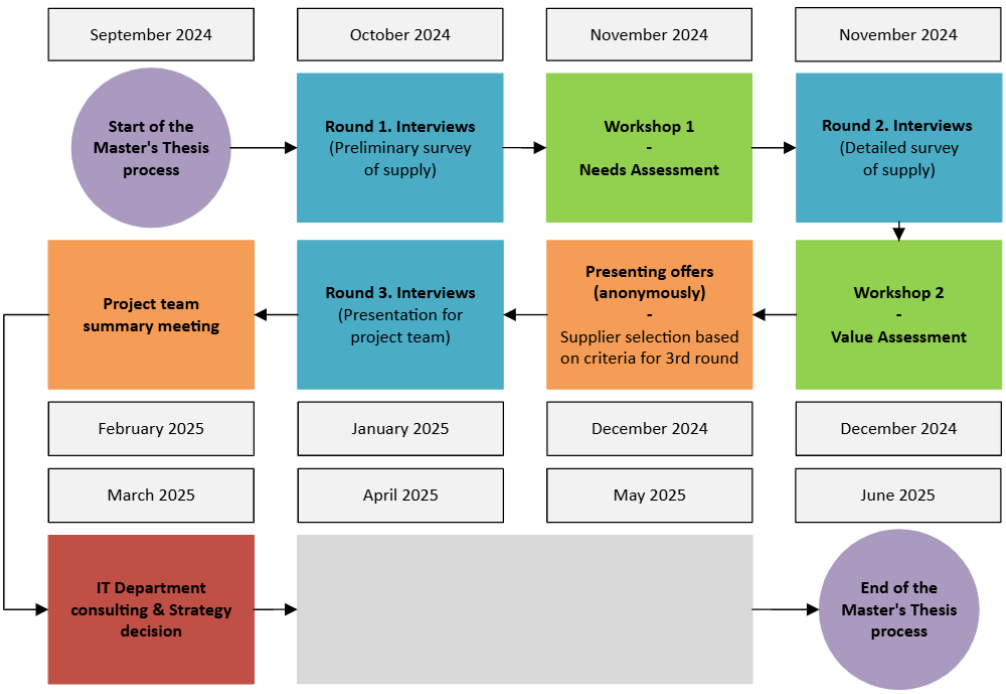


Figure 15. Process diagram of initial supplier screening related to MES acquisition

In the beginning the only requirement for system candidates was the Finnish language requirement; MES is primarily a tool for the production floor, so it needs to be available in the native language of the majority of production workers. Therefore, system candidates were search with using a search browser with the keyword *Tuotannonohjausjärjestelmä*. This keyword offered a wide range of systems including ERP systems, so it was allocated by adding *MES* after the keyword. The end result of reviewing the search results was a list of eight potential suppliers. They all were at first contacted with simple email message:

"Hello! I would be interested in hearing about your MES solution. I am doing a master's thesis (LUT, Industrial Engineering and Management) on mapping out different options."

The message was sent from the authors professional email address including contact information and referred as a project for Vexve Oy. Six suppliers out of eight corresponded with interest, one supplier refused politely (their program development was focused elsewhere), and one never replied back even though they were also reached by phone.

3.3.1 Round 1. Interviews

Official round one interviews were hold through Microsoft Teams. They all were semi-structured interviews, including six pre-determined questions given in advance:

1. *Does your MES solution have earlier integration experience with our ERP system?*
2. *What kind of user interfaces are available?*
3. *What does the "basic" package include?*
4. *What additional features are available?*
5. *How does the MES solution pay for itself from supplier point-of-view?*
6. *What is the approximate price range (initial cost, monthly cost)?*

Before the official round one interviews the author had had contact with three suppliers in Alihankinta 2024, which is a subcontracting fair in Finland. In those contacts the author had her first visual glimpse of these systems. The first two interviews shaped authors own understanding of the topic and helped to ask more focused questions in the later interviews, if they were needed – for the most part, the same themes emerged in all interviews without

any guiding towards them. The interviews disclosed that in addition to the MES, an APS system would also be needed if the intention was to automate production planning instead of only having an easy-to-use interface alongside the ERP system for production floor.

Because questions three and four were extensive in content, the author asked the interviewees to provide supporting material related to them by email. These materials were received from five suppliers.

3.3.2 Workshop 1 – Needs Assessment

Workshop 1 - Needs assessment was the first meeting of the project team, so naturally it included the introduction of the topic; what are we doing, why and how. The project team was deliberately left unaware of the suppliers involved so that there were no preconceptions or independent information seeking related to them. This was due to the perspective of the chosen approach – the aim was to find a system that meets our needs.

After the first interviews with the suppliers the author had received support materials including offered features and screenshots of the systems. These support materials could not be used as they were due to the approach perspective, so the author transformed them into a whiteboard. The features gathered from the support materials and the authors notes from interviews were transformed to be sticky notes categorized in basic and additional features. Some of these features were found in both basic and additional features due to differences between suppliers.

In the beginning of the workshop the features were shown and explained to the team members. Then the members were divided into smaller groups of three and they were instructed to assess the features through three need categories: must-have, nice-to-have and future-needs features. The number of given features were little more than sixty. The workshop was scheduled for two hours, which proved to be insufficient considering the features presented - most of the project team had assumed that the systems offered would be significantly simpler in terms of features, because MES was thought to be just a production floor friendly interface. Due to this, all team members were given homework: review and assess the features over the next two weeks. The features were sent as a list for the team members to ease the answering.

There were a lot of dispersion in the assessment of the features. Some team members asked few specifying questions about the features before answering by email. Some used their own words to describe what the system should be able to do, and the author then translated it to features. Some emailed the list back with overdraw pencil and some needed one-on-one guidance to go through the list. Some answers did not include the three need categories, so the author asked specifications by phone or by face-to-face.

As a result of the workshop and homework the author compiled a list of must-have and nice-to-have features, in both categories meaning that the feature appeared at least three times in the given answers, seen in Figure 16. Future-need features received less attention, and they were defined with smaller representation of the project team. From the supported features the author compiled a descriptive summary of the company's needs from two different point-of-views:

- Production floor employee's perspective - the MES view should provide all the information necessary to perform a task
- Operative production employee's perspective - the MES side should be able to perform the given functions instead of current ERP system.

The project team received the summary and were given a chance to comment it before the author had the second-round interview with the suppliers.

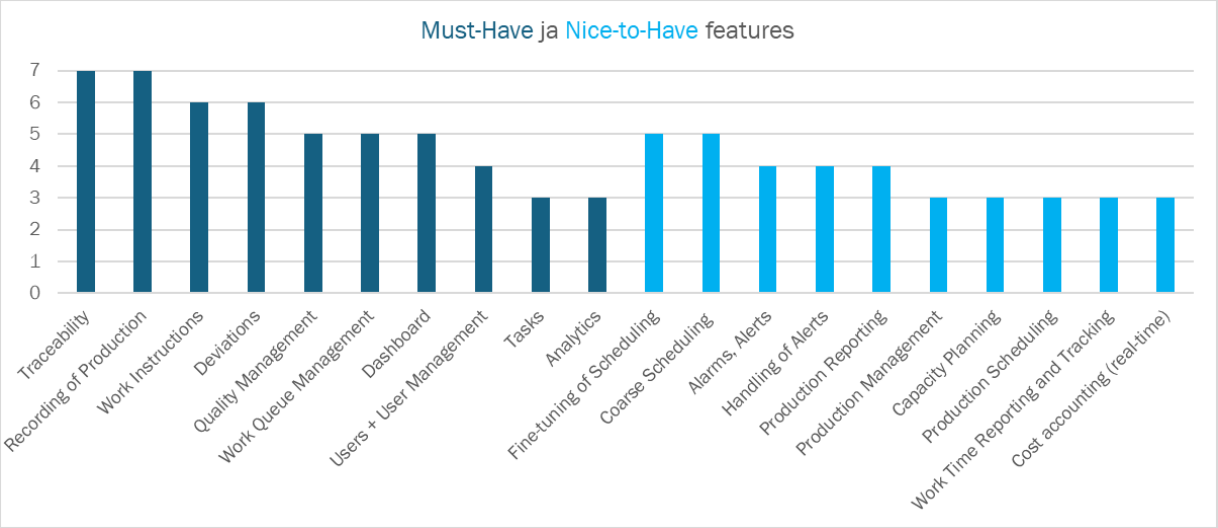


Figure 16. Identified Must-Have and Nice-to-Have features

3.3.3 Round 2. Interviews

For the second interview, also hold in Microsoft Teams, the suppliers did not receive any materials or questions beforehand. They were only informed that the project team had made the needs assessment, and the author would present the summary in the interview, which would serve as an introduction for the preliminary offer. The suppliers were shown a PowerPoint slideshow, that was send to them by email after the meeting. All the meetings were very conversational. Deadline for the preliminary offer was two to three weeks after the interview, depending on when the interview was held.

3.3.4 Workshop 2 – Value Assessment

The meaning of value needs to be unambiguous, otherwise it is likely to be understood differently by different stakeholders, which can lead to vagueness and ambiguity (Rodriguez, Mendes & Turhan, 2020). According to value-based software engineering, firstly introduced by Boehm in 2003, the economic aspect in decision-making is not enough anymore; alongside meeting the given schedules, budget and quality objects, value needs to be created by the software (Rodriguez, Mendes & Turhan, 2020). A workshop for value assessment of the identified features was hold in order to identify the value factors behind each feature; in time, the value addition will be considered when making the investment decision.

The chosen philosophy behind identifying the values, also known as value factors, was LEAN management. This was considered suitable for many reasons; as a manufacturing company Vexve Oy relies on LEAN methods in its daily functions. As stated by Junkkari & Blomberg (2018) LEAN is a management philosophy that aims to eliminate unnecessary work, from the perspective of customer and customer needs. In this case the customers were the employees which would be affected by the MES solution.

Traditionally LEAN philosophy identifies seven types of waste: overproduction, unnecessary inventory, waiting, unnecessary motion, transportation, overprocessing, and defects (Jasti & Kodali, 2015). Eighth waste, unused employee creativity / talent can also be considered. (Mulyana et al., 2023). At the beginning of the workshop, the participating eight team members answered Microsoft Forms questionnaire that would help them adjust to the LEAN mindset. The questionnaire was introductory - each question had answer options

given. The questions were taken from LEAN guide by Intotalo (Junkkari & Blomberg, 2018), which focused on knowledge work. According to the answers for the questionnaire waiting and overprocessing were the two most typical types of waste, seen in Figure 17. and 18. Least waste was identified for unused employee creativity / talent.

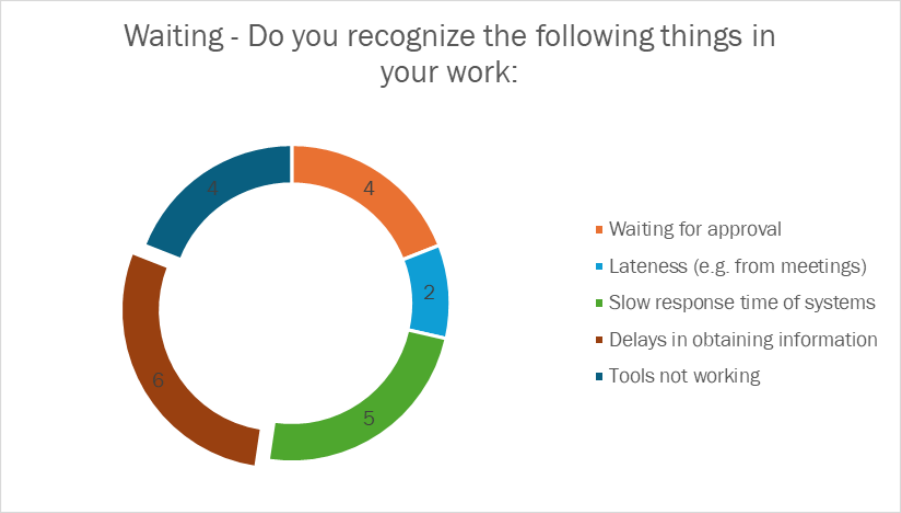


Figure 17. Answers for Waiting

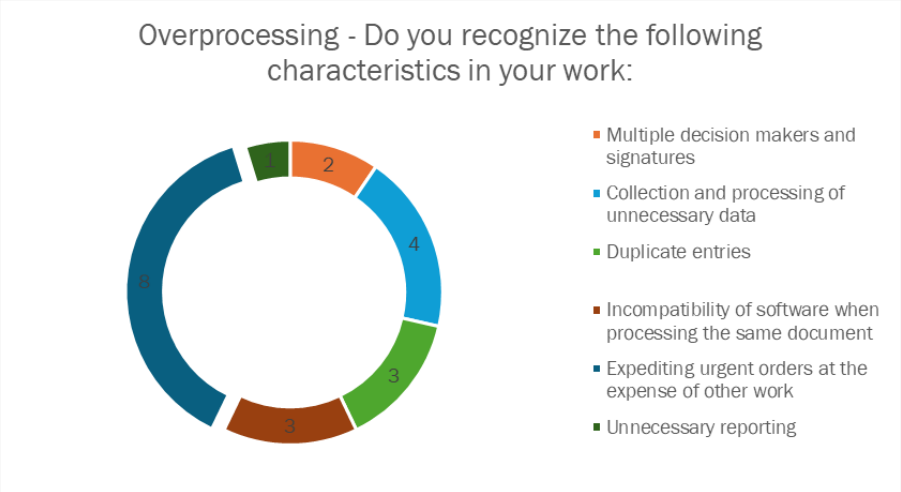


Figure 18. Answers for Overprocessing

The idea of the workshop was to define, based on the desired MES feature, the waste type and the waste to be solved by the feature. Once these were defined, then the value factor could be determined. An example is given below concerning the whole MES solution:

MES solution: The task-specific view of MES contains all the essential information for performing the task.

Waste type: Motion, Waiting

Waste: Searching for the correct dimensional drawing from PDM or email or production supervisor

Value factor: Time saving, Simplicity

Unfortunately, once again the scheduled time of two hours was insufficient and due to it the project team jointly decided to define the value factors directly based on the MES features. Luckily, the workshop was successful and the value factors for both production floor and for operative production employees were recognized, shown in Table 1.

Table 1. Value factors recognized in Workshop 2

Value factor	Production floor	Operative production employees
Transparency	x	x
Time saving	x	x
Simplicity / Ease of use	x	x
Efficiency / Cost efficiency	x	x
Clarity	x	x
Performance	x	x
Usability		x
Risk management		x
Flexibility		x
Profitability / Cost saving		x

3.3.5 Preliminary offers

After the round 2 interview the author made an excel matrix that included four separate tables: 1) table including Must-Have and Nice-to-Have features 2) table from production floor point-of-view 3) table from operative production employee point-of-view 4) system details and pricing. All six suppliers submitted their offers by the given deadline. Suppliers had freedom of the content and layout of their offers, but all of them were asked to provide clear information in their offer about whether it included all of the requested features or only a specific part of them. Suppliers were also encouraged to provide information about features that were included in the offer that we did not specifically ask for.

Three out of the six suppliers gave offers that included similar tables than the ones the author had made. The other three suppliers used verbal explanation in their offers. Four out of the six suppliers offered APS system in addition to MES, and from these three suppliers were able to offer all the asked features.

3.3.6 Presentation of preliminary offers

After receiving the preliminary offers the author gathered the information to the excel matrix made beforehand. The matrix was scored on a scale of zero to two: zero meaning the supplier does not offer the feature, one meaning that the supplier offers the feature with some restriction, and two meaning that the supplier offers the feature as requested. Originally, in addition to scoring, the intention was to define coefficients for different features based on their importance. But because the project team was unable to elevate features above others, this was not used. After scoring the results were calculated on percentages of how well the suppliers offer meets the needs. Regarding the pricing, the author defined five price categories, separately for project and monthly costs. This was due to the chosen approach perspective of finding a system that meets the needs, not to find the cheapest option. The presentation of offers was done anonymously; the suppliers were given a letter between A to F in random order.

Table 2. introduces the must-have and nice-to-have features offered by the suppliers. Five out of six suppliers were able to offer all of the must-have features. Supplier A would have been able to offer the Analytics as an add-on but chose not to offer the module due to discussion related to possible Power BI software acquisition for Vexve Oy. With nice-to-have features three out of six offered all of them. Supplier A only offered MES solution, which is reflected in the lack of APS system related features. Supplier C also only offered MES, but with little more features included than Supplier A. Supplier F offered both MES and APS system, but their offering did not include all the asked features.

Table 2. Matrix table for must-have and nice-to-have features

Must-Have (green) / Nico-to-Have (blue)	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F
Traceability	2	2	2	2	2	2
Recording of Production	2	2	2	2	2	2
Work Instructions	2	2	2	2	2	2
Deviations	2	2	2	2	2	2
Quality Management	2	2	2	2	2	2
Work Queue Management	2	2	2	2	2	2
Dashboard	2	2	2	2	2	2
Users + User Management	2	2	2	2	2	2
Tasks	2	2	2	2	2	2
Analytics	Add-on (module)	2	2	2	2	2
	18	**20**	**20**	**20**	**20**	**20**
Fine-tuning of Scheduling	Additional system	2	-	2	2	2
Coarse Scheduling	Additional system	2	-	2	2	2
Alarms, Alerts	Add-on (module)	2	2	2	2	-
Handling of Alerts	2	2	2	2	2	-
Production Reporting	1	2	2	2	2	1
Production Management	2	2	2	2	2	2
Capacity Planning	Tailor	2	2	2	2	2
Production Scheduling	Additional system	2	2	2	2	2
Work Time Reporting and Tracking	2	2	2	2	2	2
Cost accounting (real-time)	Tailor	2	-	2	2	-
	7	**20**	**14**	**20**	**20**	**13**
	63 %	**100 %**	**85 %**	**100 %**	**100 %**	**83 %**

Table 3. introduces the features related to production floor employee's perspective, where the MES view should provide all the information necessary to perform a task. Once again three out of six were able to offer all features. Supplier A could only offer BOM with visual indication of materials, not with actual figures. Supplier C was uncertain of how they could implement the printing of pallet label. Supplier F didn't offer feature for alarms and alerts, and the reporting of test results and printing a pallet label was only partially supported.

Table 3. Matrix table for features from production floor employee's perspective

Production floor employee's perspective - MES view	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F
Star / end / pause function for tasks (incl. production time tracking)	2	2	2	2	2	2
Work instructions (possibility to add task specific notification)	2	2	2	2	2	2
Dimensional drawings (item or task specific)	2	2	2	2	2	2
Bill of materials with figures or visuals	1	2	2	2	2	2
Quality gate (measurement protocol)	2	2	2	2	2	2
Deviation logging (with comment and/or picture)	2	2	2	2	2	2
Recording of production	2	2	2	2	2	2
Alarms, alerts	2	2	2	2	2	-
Traceability (melting- and stamp number)	2	2	2	2	2	2
Reporting test results	2	2	2	2	2	1
Printing a pallet label	2	2	1	2	2	1
	21	**22**	**21**	**22**	**22**	**18**
	95 %	**100 %**	**95 %**	**100 %**	**100 %**	**82 %**

Table 4. introduces the features related to operative production employee's perspective, where the MES side should be able to perform the given functions instead of current ERP system. As before, three out of six suppliers offered all the asked features. Supplier A was able to offer half of the asked features with their MES system solution. Most of the other

half would be available as tailor – meaning they could be implemented later on with pricing of their own. They did not offer OEE reporting or detail and rough planning. Supplier C was not able to offer non-production tasks opened from the MES system, but they suggested this could be done in the ERP system. They did not offer detail and rough planning, user identification or real-time cost accounting. Supplier F could only offer receiving and handling of alarms/alerts thru machine limitations. They did not offer OEE reporting or real-time cost accounting.

Table 4. Matrix table for features from operative production employee's perspective

Operative production employee's perspective - MES side	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F
Traceability reporting and monitoring (materials, registrar)	2	2	2	2	2	2
Completing the quality gate and test protocols	Tailor	2	2	2	2	2
Review of deviations	2	2	2	2	2	2
Opening non-production tasks to the work queues	2	2	1	2	2	2
Work queue management (defining employee view per work queue)	2	2	2	2	2	2
Dashboard	2	2	2	2	2	2
Receiving and handling various production alarms/alerts	2	2	2	2	2	1
Production reporting (KPI, OEE)	1	2	2	2	2	1
Capacity planning (simulation)	Tailor	2	2	2	2	2
Production management (scheduling, detail and rough planning)	1	2	1	2	2	2
User identification from the perspective of utilization and load times	Tailor	2	-	2	2	2
Real-time cost accounting	Tailor	2	-	2	2	-
	14	**24**	**18**	**24**	**24**	**20**
	58 %	**100 %**	**75 %**	**100 %**	**100 %**	**83 %**

Table 5. shows the calculated price categories for each supplier, separately for initial cost and monthly cost. Initial cost means the project costs before using the system. For comparison purposes, the table also includes the overall equivalency percentage of the three matrix tables previously presented. The pricing of the offers was confidential, so it will not be disclosed in more detail. The pricing principles were either dependent of the user amount or the license amount. All offers were with SaaS implementation. If calculated with five years usage, the suppliers A, B and F would cost nearly the same, D and E would be notably more expensive, and C notably less expensive.

Table 5. Price categories and equivalence percentages for offers

Price categories	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F
Initial cost	2B	3B	1	5	3B	2A
Monthly cost	3A	2B	2	3	5	2B
Equivalence %	*69,8 %*	*100,0 %*	*84,9 %*	*100,0 %*	*100,0 %*	*82,6 %*

The suppliers were presented to the project team with the matrix excels and some additional data gathered from the offers and earlier supplier interviews. The additional data is confidential, but it included for example other features the offered systems had, and information concerning pricing (update policy, user support). After some discussion the

project team decided to eliminate suppliers C and D. Supplier C was eliminated because their offer did not include APS system nor the possibility to acquire it later in the future. Supplier D on the other hand was eliminated because their initial cost was significantly higher than the other two suppliers who offered all features. With remaining suppliers, A, B, E and F, the project team was unable to make more eliminations, even after they asked the author to reveal the companies.

3.3.7 Round 3. Interviews and project team summary meeting

For the third and final round of interviews the suppliers were given the opportunity to present their systems to the project team as face-to-face in Sastamala or as an online meeting. The project team was content with all of the presentations, and each of them had lively dialogue. The presentations gave the first glimpse of the visual side of the systems and their user interfaces.

After all involved suppliers had given their presentation, the project team had a summary meeting. The original idea at that point was to eliminate two more suppliers and to continue with two others for reference visits. The offered systems were not identical, not even the ones of suppliers B and E that had 100 percent equivalency; all systems had their strengths and weaknesses. Due to this, the project team was not able to make any elimination, but as an option it agreed to consult the IT department with smaller team representation.

3.3.8 IT department consulting and strategy decision

The consultation of IT department included mostly confidential information that is not permitted to be published in this work. In the overall picture, the end result of the consultation was to consider what kind of solution is desired alongside the ERP system – only MES, MES and APS, only APS, completely new ERP or something else.

After the IT department consultation, the project team decided to focus only on MES solution at the time being. The remaining suppliers A, B, E & F were informed of the decision. *Author's note: From this point, the information concerning the preliminary study is confidential, due to being ongoing at the time of publication of this master's thesis.*

4 Analysis and Results

The identified challenges of production planning and daily management in the case company were related to ten different themes: change management, detail planning, deviation management, information flow, production reporting, quality gate, traceability, transparency, unnecessary work, and work that remains to be done. Almost all of these themes already emerged when the must-have and nice-to-have features were identified in Workshop 1, where the focus was on what is wanted to be done by MES solution (Figure 16).

Challenges related to change management were mostly due to unclear or mistimed communication and lack of process. Firstly, describing the process is important so that everyone works together according to the agreed rules. Timely communication is possible with MES because the necessary information can be added to the specific task, which means it is immediately available on the production floor. The MES view can be configured to update every x minutes, and the attention can be implemented with a pop-up window and visual effects. Even a read receipt can be requested if it is essential to receive confirmation that the information has been noticed. The desired state of better change management and overall communication to production floor without manual functions can be achieved with MES.

Challenges related to detail planning from production planner point-of-view could be easily solved with APS system, but not with MES only. In order to keep the detail planning updated with minimum time consumption, the current operating methods in practice should be evaluated critically. By doing small measures in between other tasks saves you from having to do a comprehensive arrangement once a week. From production floor point-of-view organizing workstations into operating smoothly without unnecessary delays can be done with MES by only giving tasks that have no obstacles available.

Challenges related to deviation management were due to the current ERP system not supporting the notification of urgent or non-urgent deviations detected at workstations, and due to not having a mutual process. The handling of urgent deviations was at good level, but the handling of non-urgent deviations was easily forgotten due to not having a system to log the information. For better handling of all deviations, it is possible to have them logged in

the relevant task at MES, from where a log will be created and related actions can be recorded. It is even possible to handle the communication automatically; an email or SMS can be sent automatically to the receiver of the deviation.

Challenges related to information flow were diverse and multidirectional. The information might be given too early or too late, and therefore it was not available at the moment of need, or the information never reached the relevant persons. Efficient information flow between all parties can be achieved by making the necessary information available to everyone, regardless of time and place, as soon as possible. This can be achieved by MES; information can be added as pop-up notifications for tasks or even when entering the work queue view. These can be shown once or multiple times. Other information, for example measurement drawings, can be added to tasks.

Challenges related to production reporting were due to different ways of operating, having multiple tasks open for specific item, or not being able to correct an incorrect entry. The desired state of more accurate and real-time reporting (and information) from production floor can be achieved with MES. Inputs made for a specific task can be made easily visible for all employees producing the same task with time stamps. For example, it is possible to require recording of completed quantity before checking out the system. With MES work queue only the correct task for specific item needs to available for specific workstation, once the previous phase is complete. So-called negative reporting is not available for production floor at current ERP system due to it needing certain features that can cause errors too easily, but with MES tasks it can be made available easily.

Challenges related to quality gate were filling out the dimensions to excel sheets from production floor and from operative point-of-view, keeping the desired dimensions up to date in the excel sheets. With MES the external excel sheet can be forgotten and the measurement during production can be made to be a part of the task, not a separate function. Another advantage is the secure login of the registrar's identity, as MES login IDs are personal. Keeping up the desired dimensions requires change in operation methods; it should be included in the revision process.

The main challenge related to traceability was ensuring that the correct heat number goes through the production chain. The current ERP system does not support collecting heat numbers when goods arrive and therefore, they are not put into the system, from where they then could be focused to specific task. Instead, the information travelled with the goods until it was recorded to excel or paper, and due to it there was a possibility for incorrect or missing heat number. With MES this could be avoided by requiring informing the heat number related to specific task, from which a database can be created.

Challenges related to transparency were perhaps the most difficult ones: no possibility to view the production status of a specific order, no real-time KPIs or stock levels or capacity levels available, even withheld information between departments. Visibility throughout the production chain can be achieved with MES by creating a dashboard with relevant information. It can include for example information about possible or probable delays, show the current capacity levels for certain items or workstations, and have relevant real-time KPIs. Making the whole supply chain transparent inside the company needs more than MES can offer, but it is a step in the right direction.

Challenges related to unnecessary work were doing same thing separately for two different places and still not having identical information and reaching out production or operational employees with inefficient means. In order to ensure that work queues in ERP system are up to date, a change in operation methods is required, even though this problem can be solved by MES; no more need for separate worklist, only giving the right tasks available in the right order. But even with MES it is necessary to have the tasks in order at the ERP system. Inefficient means of reaching employees must be covered by agreeing on common rules of communication: when to call and when to find someone face-to-face, or with MES, when the information can be provided written or as a document. The desired state of having less non-value adding activities requires common approach and understanding of doing value adding activities instead.

Challenges identified as work that needs to be done were due to the production planners and production supervisor not having time to do tasks that are irrelevant at the moment, but important for the future. These were related to data gathering, which can be done automatically by MES. It also gives more accurate data without effort, as desired, and reduces the amount of excel sheets required.

The available MES solutions included in the case study all met the must-have features defined by the case company. With the nice-to-have features, there was a fairly large dispersion between them. From production floor employee's perspective, the offered MES solutions were more similar than from the operative production employee's perspective. The overall equivalence varied from 70% to 100%. If all features related to APS system are removed from the case study tables, then the overall equivalence would vary from 79% to 100%. This increases the equivalence of the MES solution offered by Supplier A and C, while decreasing the equivalence of the MES solution offered by Supplier F as shown in Table 6.

Table 6. Price categories and equivalence percentages for offers without APS features

Price categories	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F
Initial cost	2B	3B	1	5	3B	2A
Monthly cost	3A	2B	2	3	5	2B
Equivalence %	*78,9 %*	*100,0 %*	*88,2 %*	*100,0 %*	*100,0 %*	*80,3 %*
Change %	9,2 %	-	3,3 %	-	-	-2,3 %

5 Discussion

According to Shojaeinasab et al. (2022) MES was developed to address the inadequacy of ERP systems. The case company identified that the challenges described in the previous chapter were partly due to the inflexibility of the current ERP system and partly to its inadequate features in relation to practical actions. Fei (2010) stated that from theoretical point-of-view the purpose of MES is to collect real-time data and maintain two-way communication of production floor and operative employees. According to Beric at al. (2018) main benefits of MES, when comparing to only having ERP system, were better information flow, more efficient production planning and quality assurance, and simpler monitoring of production. Initially, the case company was interested in MES as an easy-to-use interface for production floor, but during the case study the company representatives understood the available possibilities offered by MES for other functions.

Govindaraju & Putra (2016) listed the achievable goals of MES implementation as reductions (less time used to maintain manufacturing documents, lower WIP levels by reducing lead times, smaller amount of missing production lots, lower operational costs), improvement of data quality, better visibility and transparency of the production chain, enhanced decision-making with real-time data, and optimization of entire supply chain with better workflow control. The goals for the case company were doing less non-value adding activities, collecting more accurate data and generating logs automatically, getting rid of multilevel excel sheets, enhanced information flow between all parties, having more accurate and real-time reporting and information from production floor, and making sure that the right information is available at the right place at the right time in the right format.

The research conducted by Järvenpää et al. (2015) recognized that Finnish manufacturing companies' production floor level functions were not supported by proper IT-tools, instead, excel was used to support many functions that required rapid reacting in the event of disturbance or change. In addition, the research stated that all participated companies used ERP system, excel and paper & pen to plan, schedule and control their production. In cases of disturbances leading to re-scheduling needs, the lack of integration between ERP system and excel led to situations where the re-scheduling was only done at the production floor, leaving no trace of data. Quality data was also commonly gathered to a separate system. In

the case company the use of insufficient IT-tools could still be identified to be the situation ten years later: excels are used for many functions due to ERP systems deficiencies. Situations requiring quick response, such as manufacturing a valve related to a claim, are often performed timely outside the system due to re-scheduling needing manual work, leaving the impact on the overall picture of production somewhat unnoticed.

Järvenpää et al. (2015) identified production floor disturbances to be caused by rush orders, machine breakdowns, unavailability of components and supplier component defect. In the case company the typical disturbances are caused by rush orders or machine breakdowns. Reporting of KPIs was typically done once a month, due to needing to gather the relevant data from various sources (Järvenpää et al., 2015). Ten years forward, the reporting of KPIs is still only done in monthly level at the case company, due to the same reason. Järvenpää et al. (2015) discovered that the majority of participated companies theoretically instructed that defected items should be stopped at the workstation, but in practice defects were corrected in later workstations, leading to hidden quality issues, making it hard to eliminate the defects from happening again in the future. At the case company this occurs infrequently, but similar situations can be identified. The defects are corrected manually instead of correcting them for example in the machining phase, where it might take significantly less time and would eliminate the possibility of the defect happening again.

For the participant companies it was typical that detail scheduling was only done on day's accuracy. The challenge for having longer accuracy were the average loads of the items; they were not based on reliable data from actual loads. Another challenging factor for detail scheduling was the lack of proactive machine maintenance scheduling and its capacity reduction. (Järvenpää et al., 2015.) In the case company detail planning is made for longer period of time, but the same challenges affect the accuracy of the schedule: used load times are average and they vary from many reasons, depending on the workstation. In machining the variation can be due to material quality and in assembly dependent on the employee performance. The maintenance of machines is informed to the production planning once it has been agreed, but the information remains outside the ERP system.

6 Conclusions

The objective for this master's thesis was to identify challenges related to production planning and daily management in manufacturing companies and to examine how MES can solve these challenges. The theoretical approach used was literature review and the practical approach used was a case study, where the author's employer served as the commissioner and gained a preliminary study on the MES options available on the market in relation to their identified needs. The research was limited to only solving the identified problems with the acquisition of MES in addition to the current ERP system, other software options and practical actions were excluded.

The impact of this master's thesis can be considered to be the conclusion that the mere passage of time does not eliminate the problems identified in the manufacturing industry, but they can be considered to remain the same if the problems are not solved in a solution-oriented manner. In practice this research will hopefully help manufacturing companies to identify their own challenges and provide ready-made solution proposals.

Three research questions were set for this master's thesis, the answers to which are briefly summarized below. The answers to the questions are discussed in more depth in chapters 2.3. Finnish manufacturing companies current state and challenges (challenges according to research), 3.2.2. Identified challenges (challenges identified in the case company), 3.3.6. Presentation of preliminary offers (offered MES solutions), and 4. Analysis and Results.

RQ1: What kind of challenges related to production planning and daily management can be identified in a manufacturing company?

Variety of challenges related to production planning and daily management can be identified in a manufacturing company. The findings from the literature review and the case study support each other, even though the time window between the most significant study (Järvenpää et al., 2015) and this research was ten years. The challenges are partly due to the use of inadequate ERP systems with unintegrated systems used to fill in the absence of functions. Some challenges are due to practical approaches, mostly because the lack of process description. Figure 19 summarizes the challenges identified by theme and the functions related to them.

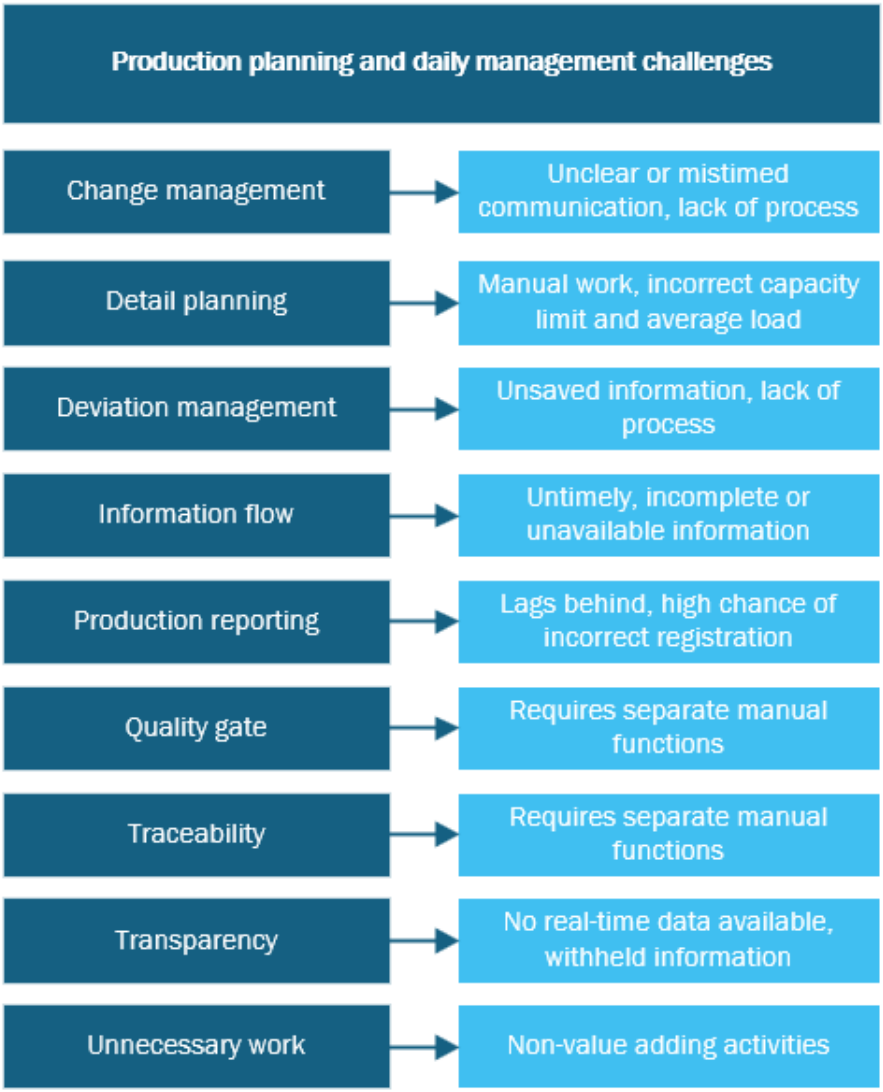


Figure 19. Identified production planning and daily management challenges

RQ2: How can a manufacturing execution system help solve these challenges?

Majority of the identified challenges can be solved with MES: some challenges can be solved completely, others partially, while also requiring changes in practical approaches. The only identified challenge that can't be solved with MES is related to detail planning: it would require acquiring APS system. For production floor point-of-view improvements can be made with MES, but from operative employee point-of-view it does not solve the challenge. Figure 20. summarizes the solutions offered to solve the identified challenges by MES by theme and the functions related to them.

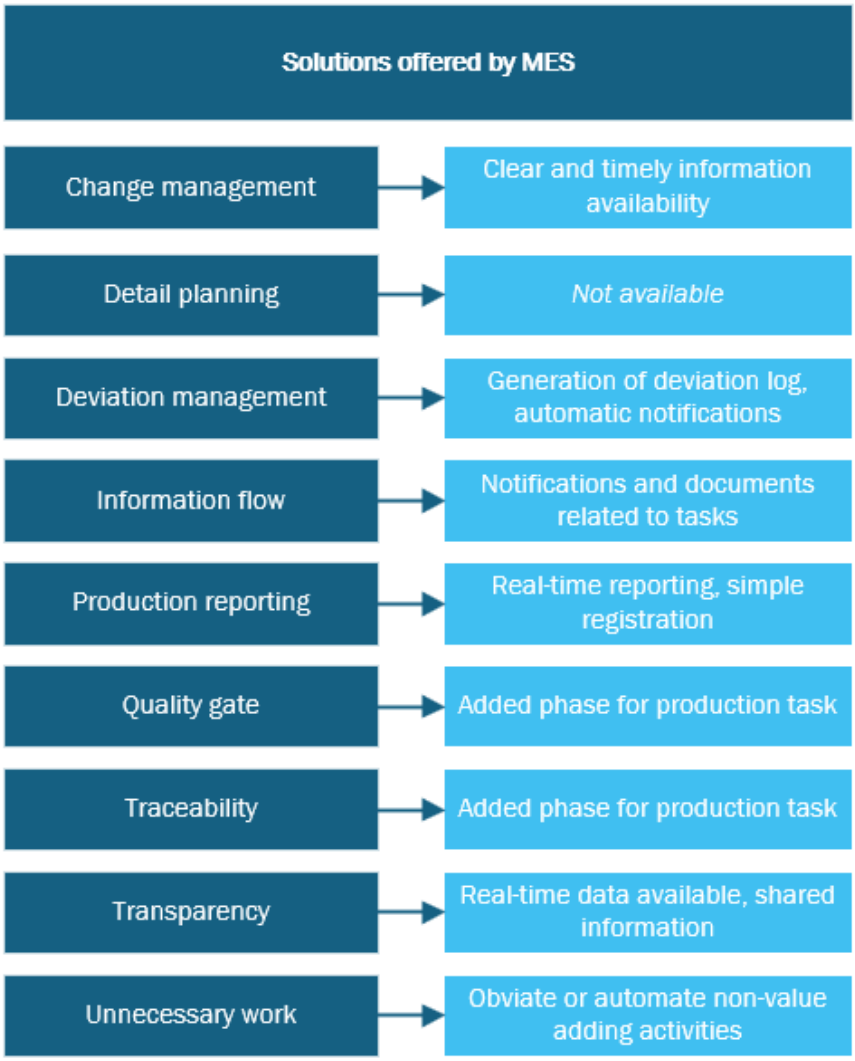


Figure 20. Solutions for identified challenges offered by MES

RQ3: How does the available MES solutions meet the case company's needs?

Three of the selected suppliers for the case study were able to provide all the requested features, whereas the other three were able to provide most of the features. The must-have features were in principle offered by all of the suppliers; analytics was not offered by Supplier A due to informing the possibility of acquiring Power BI. From production floor employee's perspective, the difference between offered MES solutions can be said to be minor. Overall, it can be said that all suppliers were able to offer a MES solution that suited the case company's needs. It can therefore be stated that the consideration of MES for the case company is targeting the right system as a tool for production planning and daily management.

For future research other available options solving production planning and daily management challenges should be studied. Many of the challenges could be resolved without a separate system, by changing practical operations and by describing processes, so that everyone would have common operating methods. This kind of study would be especially useful from the perspective of smaller companies, which may not be able to afford an expensive system investment, even if it will eventually pay off. However, the usefulness and practicality of MES should not be underestimated, as it is a system that aims to provide an easy-to-use interface for a variety of needs.

References

Beric, D., Stefanovic, D., Lalic, B. & Cosic, I. 2018. The Implementation of ERP and MES Systems as a Support to Industrial Management Systems. International Journal of Industrial Engineering and Management. Vol. 9, no 2, p. 77-86. DOI 10.24867/IJIEM-2018-2-109

DevCo. 2024. Vexve Armatury Group companies join their forces under the Vexve brand. [Web page]. [Cited 10.1.2025]. Available at: https://www.devco.fi/newsfeed/vexve-armatury-group-companies-join-their-forces-under-the-vexve-brand

DIMECC. 2016. MANU – Future Digital Manufacturing Technologies and Systems. Final Report. DIMECC Publications Series No. 10. Available at: https://teknologiainfo.net/fi/content/manu-future-digital-manufacturing-technologies-and-systems

Duesbery, L. & Twyman, T. 2021. 100 Questions (and Answers) About Action Research. Thousand Oaks: SAGE Publications, Inc. [Cited 16.5.2025]. DOI: https://doi.org/ 10.4135 /9781544305455

Dutta, G., Kumar, R., Sindhwani, R. & Singh, R Kr. 2022. Overcoming the barriers of effective implementation of manufacturing execution system in pursuit of smart manufacturing in SMEs. Procedia Computer Science. Vol. 200, p. 820-832. DOI https://doi.org/10.1016/j.procs.2022.01.279

EMQ Technologies Inc. 2023. Exploring ISA95 Standards in Manufacturing. [Blog]. [Cited 31.3.2025]. Available at: https://www.emqx.com/en/blog/exploring-isa95-standards-in-manufacturing

Eskolin, J. 2018. LEAN Daily Management – Oleellisen äärellä. [Blog]. [Cited 15.5.2025]. Available at: https://www.sujuvadsgn.fi/lean-daily-management-oleellisen-aarella/

Fei, L. 2010. Manufacturing Execution System Design and Implementation. IEEE 2010 2nd International Conference on Computer Engineering and Technology. Vol. 6, p. V6-559-V6-562. DOI 10.1109/ICCET.2010.5486065

Fleischmann, B., Meyer, H. & Wagner, M. 2015. Supply Chain Management and Advanced Planning. Fifth edition. Berlin, Heidelberg: Springer Berlin. [Cited 15.5.2025]. DOI 10.1007/978-3-642-55309-7__4

Govindaraju, R. & Putra, K. 2016. A methodology for Manufacturing Execution Systems (MES) implementation. IOP conference series. Materials Science and Engineering. Vol.114, p. 12094-12103. DOI 10.1088/1757-899X/114/1/012094

Hakanson, B. 1996. MES stands for manufacturing improvements. Industrial Engineer (Norcross, Ga.). Vol 28, issue 2, p. 27-28. ISSN: 2471-9579

International Society of Automation. N.d. ISA-95 Series of Standards: Enterprise-Control System Integration. [Web page]. [Cited 31.3.2025]. Available at: https://www.isa.org/standards-and-publications/isa-standards/isa-95-standard

Jasti, N.V.K. & Kodali, R. 2015. Lean production: literature review and trends. International Journal of Production Research. Vol. 53, no. 3, p. 867-885. DOI https://doi.org/10.1080/00207543.2014.937508

Junkkari, J. & Blomberg, U. 2018. Intotalo Oy - LEAN Turha työ vähemmäksi. [Web guide]. [Cited 17.2.2025]. Available at: https://www.intotalo.com/vinkit/oppaat/lean-ja-kuinka-teet-vahemman-turhaa-tyota-opas/

Järvenpää, E., Lanz, M., Tokola, H., Salonen, T. & Koho, M. 2015. Production planning and control in Finnish manufacturing companies – Current state and challenges. In International Conference on Flexible Automation and Intelligent Manufacturing.

Kiran, D.R. 2019 Production planning and control: a comprehensive approach. Oxford, United Kingdom: Butterworth-Heinemann, an imprint of Elsevier. ISBN: 9780128189375.

Lean Thinking Oy. N.d. LEAN sanasto. [Web page]. [Cited 15.5.2025]. Available at: https://leanthinking.fi/sanasto/daily-management-paivittaisjohtaminen/

Mantravadi, S. & Møller, C. 2019. An Overview of Next-generation Manufacturing Execution Systems: How important is MES for Industry 4.0? Procedia Manufacturing. Vol. 30, p. 588-595. DOI 10.1016/j.promfg.2019.02.083

Mantravadi, S., Srai, J.S. & Møller, C. 2023. Application of MES/MOM for Industry 4.0 supply chains: A cross-case analysis. Computers in Industry. Vol. 148. DOI https://doi.org/10.1016/j.compind.2023.103907

Moran, J. 1991. Leading the organization to perfection through daily management. National Productivity Review. Vol. 10, issue 3, p. 369–378. DOI https://doi.org/10.1002/npr.4040100309

Mulyana, I.J., Singgih, M.L., Partiwi, S.G. & Hermanto, Y.B. 2023. Identification and Prioritization of Lean Waste in Higher Education Institutions (HEI): A Proposed Framework. Education Sciences. Vol. 13, issue 2. DOI https://doi.org/10.3390/educsci13020137

Nicholas, J. 2018. Lean Production for Competitive Advantage: A Comprehensive Guide to Lean Methods and Management Practices. Second edition. Florida: Productivity Press. [Cited 15.5.2025]. Available at: https://ebookcentral.proquest.com/lib/lut/detail.action?docID=5323461&pq-origsite=primo

Nicholas, J. 2023. Lean daily management in healthcare: origins, practices, and associations with lean leadership and lean sustainability. Total Quality Management. Vol 34, no. 12, p. 1526-1552. DOI https://doi.org/10.1080/14783363.2023.2182677

Rodriguez, P., Mendes, E., & Turhan, B. 2020. Key Stakeholder's Value Propositions for Feature Selection in Software-Intensive Products: An Industrial Case Study. IEEE Transactions on Software Engineering. Vol. 46, issue 12, p. 1340-1363. DOI 10.1109/TSE.2018.2878031

Saenz de Ugarte, B., Artiba, A. & Pellerin, R. 2009. Manufacturing execution system – A literature review. Production Planning and Control. Vol. 20, issue 6, p. 525-539. DOI 10.1080/09537280902938613

Shojaeinasab, A., Charter, T., Jalayer, M., Khadivi, M., Ogunfowora, O., Raiyani, N., Yaghoubi M. & Najjaran, H. 2022. Intelligent manufacturing execution systems: A systematic review. Journal of Manufacturing Systems. Vol. 62, p. 503-522. DOI https://doi.org/10.1016/j.jmsy.2022.01.004

Syrjälä, K. 2017. DIMECC MANU-ohjelman projektien esittely. Hitsaustekniikka. Vol. 1, p. 4-5. Available at: https://www.dimecc.com/wp-content/uploads/2016/08/HT_1_17_Syrja%CC%88la%CC%88_Kai.pdf

Tabim, V.M., Ayala, N.F., Marodin, G.A., Benitez, G.B. & Frank, A.G. 2024. Implementing Manufacturing Execution Systems (MES) for Industry 4.0: Overcoming buyer-provider information asymmetries through knowledge sharing dynamics. Computers & Industrial Engineering. Vol. 196. DOI https://doi.org/10.1016/j.cie.2024.110483

Vexve Oy. N.d. Company. [Web page]. [Cited 10.1.2025]. Available at: https://www.vexve.com/en/company

Vexve Ball Valves presentation. N.d. Marketing materials.

Vilkka, H. 2023. Kirjallisuuskatsaus metodina, opinnäytetyön osana ja tekstilajina. Helsinki: Art House. [Cited 16.5.2025]. Available at: https://www.ellibslibrary.com/reader/ 9789518 849448

Younus, M., Peiyong C., Hu, L. & Yuqing, F. 2010. MES development and significant applications in manufacturing - A review. 2nd International Conference on Education Technology and Computer. Vol.5, p.V5-97-V5-101. DOI: 10.1109/ICETC.2010.5530040

Zhang, Y. & Wildemuth, B.M. 2017. Unstructured Interviews. In: Wildemuth, B.M. (ed.). Applications of Social Research Methods to Questions in Information and Library Science. Second edition. California: ABC-CLIO, LLC. [Cited 16.5.2025]. Available at: https://www.drghazi.net/media/drghazi/documentary8.pdf