UNIVERSITY OF VAASA

SCHOOL OF TECHNOLOGY AND INNOVATIONS

ENERGY PRODUCTION

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SUPPLY CHAIN DIGITALIZATION – OPTIMIZING THE FACTORY MATERIAL FLOW

Master`s thesis for the degree of Master of Science in Technology submitted for inspection

Vaasa 6.3.2020

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ACKNOWLEDGEMENTS

This Master's thesis has been done with co-operation for company located in Vaasa. I would like to thank the company for the opportunity make this thesis.

From company I would like to than my instructors Terhi Ylisirniö and Pekka Ritari for their help and support for the thesis.

From university of Vaasa I would like to thank my thesis supervisor Birgitta Martinkauppi for guidance and help on my thesis.

In Vaasa 6.3.2020

Joni Hautala

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SYMBOLS AND ABBREVIATIONS

AR	Augmented Reality
ASN	Advance Shipping Notice
ATP	Available to Promise
BOM	Bill of Material
CPPS	Cyber-Physical Production System
CPS	Cyber-Physical Systems
ECC	ERP Central Component
E- BOM	Manufacturing Bill of Material
ERP	Enterprise Resource Planning
ETO	Engine to Order
EWM	Extended Warehouse Management
HR	Human Resources
IBP	Integrated Business Planning
IIoT	Industrial Internet of Things
iOS	Iphone OS
IoT	Internet of Things
LoB	Lines of Business
M- BOM	Engineering Bill of Material
MFS	Material Flow System
PDM	Product Data Management
PDS	Production Data Structure
PEO	Production Engineering and Operations
PLM	Product Lifecycle Management
PP/DS	Production Planning / Detail Scheduling
RF	Radio Frequency

SAP	Systeme, Anwendungen und Produkte in der Datenverarbeitung
SCADA	Supervisory Control and Data Acquisition
SCM	Supply Chain Management
S&OP	Sales & Operations Planning
TM	Transportation Management
UI	User Interface
VR	Virtual Reality
WIP	Work in Process
WLAN	Wireless Local Area Network
WM	Warehouse Managed

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VAASAN YLIOPISTO
Teknillinen tiedekunta
Tekijä: Joni Hautala
Tutkielman nimi: Toimitusketjun digitalisointi – Tehtaan toimitusketjun optimointi

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Tutkinto: Diplomi-insinööri
Oppiaine: Energiatekniikka
Opintojen aloitusvuosi: 2014
Tutkielman valmistumisvuosi: 2020 **Sivumäärä:** 75

TIIVISTELMÄ

Nykypäivän kiristynyt kilpailu ja edistyneet toimitusketjut edellyttävät entistä parempaa tomistusketjun digitalisointia parantamaan tehokkuutta, toimistusvarmuutta ja yrityksen kannattavuutta. Toimitusketjun digitalisoinnin avulla voidaan tukea reaaliaikaisesti muuttuvaa kysyntää valmistusyksikössä, luomalla älykäs toimitusketju joka tukee kysyntälähtöistä arvoketjua.

Tämän tutkimuksen tarkoituksena on selvittää ja esittää kohdeyritykselle mahdolliset toiminallisuudet ja tuotteet SAP S/4HANA:sta jotka tukevat kohdeyrityksen nykyisiä ja suunniteltuja toimitusketjun prosesseja. Työssä tutkitaan hankinnasta, varastonhallintaan ja valmistukseen liittyviä toiminallisuuksia. Toiminnallisuudet analysoidaan kohdeyrityksen näkökulmasta ja verrataan vaatimuksiin, joita kohdeyrityksessa nostetaan esille. Tutkielman teoreettinen osuus pohjautuu toimitusketjun ja ERP SAP uuteen tuotteeseen SAP S/4HANA. Toimitusketjun osuudessa tuodaan esille, kuinka vaatimukset Toimitusketju 4.0 ja Teollisuus 4.0 voidaan nähdä suuntaviivoina SAP S/4HANA:n kehitykselle. Empiirinen osuus jakautuu kahteen tutkimuskysymykseen: Mitkä ovat tulevaisuuden mahdollisuudet visualisoida, arvioida ja optimoida toimitusketjua SAP S/4HANA ydintoiminnoilla? Mitä hyötyä kohde-yritys voi saavuttaa ottamalla käyttöön SAP S/4HANA laajennetut toiminallisuudet?

Työn tuloksena saatiin ymmärrys SAP S/4HANA tuotteesta ja sen mahdollisuuksista toimitusketjun osalta. SAP S/4HANA tuotteena tukee monia kohdeyrityksen vaatimuksia ylätasolla, mutta vaatii konkreettisempia tutkimuksia ja testausta kohdeyrityksen työskentely ympäristössä sekä pitäisi hyödyntää kohdeyrityksen dataa.

AVAINSANAT: SAP, SAP S/4HANA, Materiaalivirta

UNIVERSITY OF VAASA

VAASA UNIVERSITY
Faculty of Technology
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Topic of the Master`s Thesis: Supply Chain Digitalization – Optimizing the Factory Supply Chain

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Major subject: Energy Technology
Year of Entering the University: 2014
Year of Completing the Master's Thesis: 2020 **Pages:** 75

ABSTRACT

Today's increasing competition and advanced supply chain needs better digitized supply chain to improve efficiency, on time delivery and business profitability. Supply chain digitalization enable to have real- time optimized supply chain. Supply chain management supporting the variable manufacturing unit demand by creating smart supply chain that supports the demand-driven value chain.

The purpose of the study is to investigate and present how the SAP S/4HANA functionalities and products could support the case company and defined supply chain processes. The study explores supply chain from purchasing, inventory management to manufacturing. Functionalities are analysed from case company perspective and are compared to requirements what case company has raised up. Theoretical chapters focus on the supply chain and ERP SAP new product SAP S/4HANA. Supply chain chapter is divided to Supply 4.0 and Industry 4.0 to bring up the view how the SAP S/4HANA is aligned with these topics. Empirical part is divided into two research questions: What are the future capabilities to visualize, evaluate and optimize the supply chain including the core functionalities of the SAP S/4HANA? What benefits the case company can achieve by implementing the extended functionalities of the SAP S/4HANA?

As a result of the study a good understanding of the SAP S/4HANA product and the possibility related to supply chain was reached. SAP S/4HANA as a product supports most of the requirements from case company in high level but requires more specific research and testing in company environment with real company data.

KEYWORDS: SAP, SAP S/4HANA, Material flow

1 INTRODUCTION

The goal of this thesis is, discuss and apply theoretical reference with practical results regarding evaluating SAP S/4HANA for the case company. For making change from SAP ECC to SAP S/4HANA is change in technical side but also gives possibility to make next steps in business process change. In larger company as case company is, the ERP system upgrade is a large project. The project starts with making as is assessment to have a clear big picture of the current way of working, and after that understand value what the SAP S/4HANA portfolio can bring in future.

1.1 Background of the Study

The need of this thesis arose when the company decided that the SAP ERP Central Component (ECC) will be migrated to SAP S/4HANA in future, and investigation of the future tools and way of working is ongoing. In this thesis target is to investigate how real-time optimized supply chain management could support meeting the variable manufacturing unit demand by creating smart supply chain that supports the demand-driven value chain. In the scope is to investigate the future capabilities to visualize, evaluate and optimize the supply chain including the core functionalities of the SAP S/4HANA and Integrated Business Planning.

1.2 The Objectives of the Study

The purpose of the study is to investigate how the real – time optimized supply chain management could support meeting the variable manufacturing unit demand by creating smart supply chain that supports the demand-driven value chain. To be able to find out solutions to these the thesis is divided to separate theoretical and empirical parts, by answering two research questions

RQ 1: What future capabilities of SAP S/4HANA could support manufacturing material flow / logistics in case company?

RQ 2: How the supporting supply chain solutions of the extended functionalities in SAP S/4HANA is giving benefits for case company?

The objectives to the theoretical part are to create knowledge about the Supply chain 4.0, SAP S/4HANA and the benefits of the system. The objectives to the empirical part of the thesis is to give answers to the second research question, what could be the practical benefits for the case company when implementing the new solution.

The personal objectives are learn more about the SAP S/4HANA, how the system is working, and what benefits the implementation can bring to the case company. The cooperation with the different organizations gives good knowledge about manufacturing, production planning, material management, supply chain management and how the company should be developed when thinking the smart manufacturing, digitalization and IT landscape.

1.3 Key Concept and the Limitations of the Study

The key concepts in this thesis are: SAP S/4HANA, material flow and manufacturing flexibility. First key concept SAP S/4HANA is an intelligent ERP solution enables companies to: digitize the finance processes, take control of supply chain, stay ahead of procurement needs, manage lifecycle effectively, achieve insights across business and develop industry specific functionalities. (SAP, 2019). In this thesis the focus areas are in the supporting supply chain solutions and procurement needs. The SAP S/4HANA is described more in detail in page 23. Second key concept supply chain digitalization is highlighted, because it is the SAP S/4HANA area where this thesis will be focusing. To understand the capabilities, to visualize, evaluate and optimize the supporting supply chain process the Supply chain 4.0 etc has been opened in more details. Third key concept is manufacturing flexibility, where understanding and utilizing the technologies, processes and competence to fulfil the customer needs and requirements.

1.4 Structure of the Study

The structure of this thesis is divided into theoretical part and empirical part. The theoretical part will build the foundation for empirical findings and provide answers to the first research question. The theoretical part is divided into two chapters: Industrial 4.0 and SAP S/4HANA platform. The first chapter describe Industrial 4.0 and introduce how the Industry 4.0 has impacted to the supply chain. Collaboration with suppliers, manufacturers and customers is constantly increasing and the target is to share real time data to have end-to-end visibility. The second chapter of the theory describes the SAP and SAP S/4HANA and will go through the functionalities SAP S/4HANA. The chapters gather processes and features which supports the case company needs.

The empirical chapter of the thesis present the research findings and the research process. The chapter is divided into two parts: case company requirements mapping focusing warehousing of the new available solutions and data analysis of in-depth meetings. The user requirements of the SAP S/4HANA are listed to provide the understanding of the gaps between current solution and new possibilities. Data collection and analysis meetings were divided into process phases, to get the results from the research in end-to-end perspective.

2 Supply Chain

This chapter is for introduce supply chain, what the supply chain management and industry 4.0 has been changing manufacturing environment. The target is to have overall picture of the supply chain and how to manage the digital transformation in Industry 4.0.

Supply chain 4.0 – the IoT applications, advanced robotics, and the advanced analytics of big data in supply chain management. “Place sensors in everything, create networks everywhere, automate anything, and analyse everything to significantly improve performance and customer satisfaction” (McKinsey, 2016).

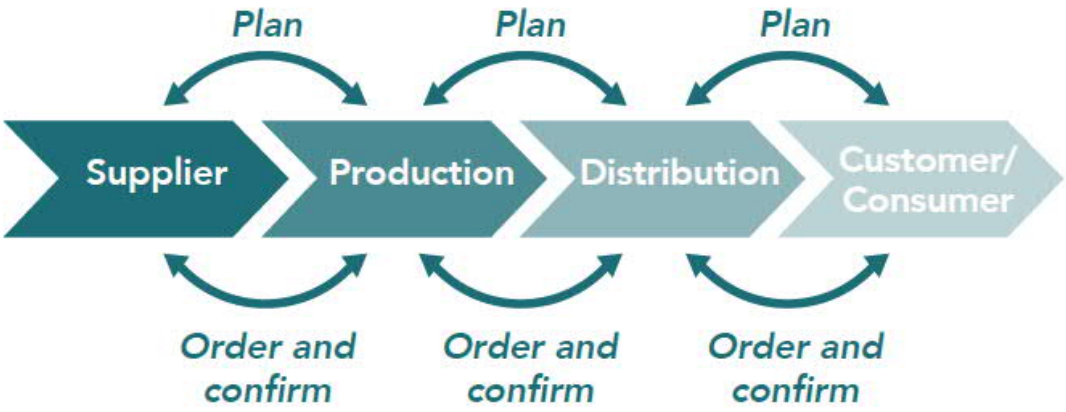

Figure 1. Supply Chain model. (Ferrantino, 2019)

Industry 4.0 as applications are the approach for the Supply chain 4.0. In Figure **1** the supply chain process described from design and planning to production, distribution and consumption needs to be mapped with the technologies in Industry 4.0. (Ferrantino, 2019)

2.1 Supply Chain 4.0

Industry 4.0 for companies has created a disruption and requirements to redesign and think their supply chain. Adapt the supply chain can achieve the next level of operation effectiveness, leverage digital business models in supply chain and transform the company to digital supply chain. Re-organization of supply chain from the design and planning, production, distribution, consumption and logistics reverse by using the industry 4.0 is called Supply chain 4.0 (Figure **2**). The digitalization for the supply chain brings to company possibility to react faster, gives more flexibility reacting changing demand or supply changes and more granular and accurate. (McKinsey, 2016)

Key technologies involved in Supply chain 4.0 are:

- Big data/analytics
- The internet of things
- Robotics
- 3D printing
- Artificial intelligence/machine learning (IDB, 2019)

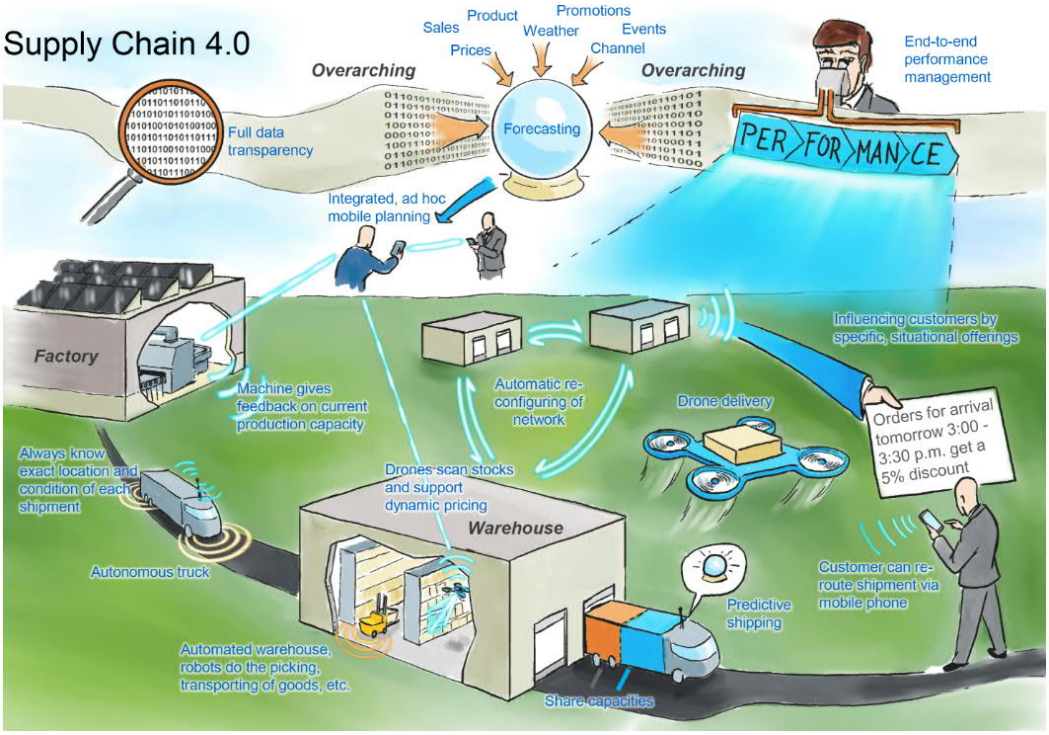

Figure 2. What could digitization bring about a Supply chain 4.0. (McKinsey, 2016)

Processing extremely large data sets, big data has a capability which can be used for example in understanding market behaviour for consumer or forecasting demand to predictive maintenance and quality control. The internet of things (IoT) to generate a complete vision of the organization behaviour, to give feedback to supply chain network of the manufacturing statuses. Robotics give stability to repetitive tasks and understand the capacity and lead times. 3D printing is way of reach the additive manufacturing to create objects by printing adhesive materials, example polymers. Machine learning and artificial intelligence are technologies with common base. Machine learning is application, which is supporting the system to automatically learn, to avoid preprograming. (IDB, 2019)

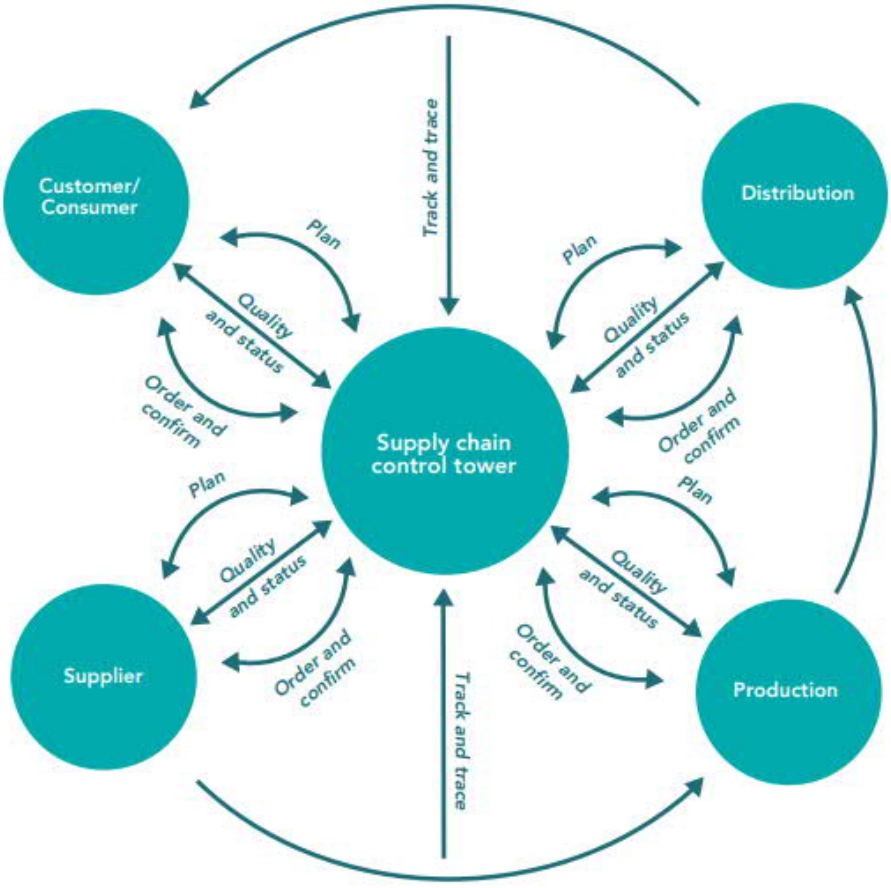

Figure 3. Integrated Supply chain ecosystem. (Ferrantino, 2019)

The Supply chain 4.0 as a term can be connected to part of integrated supply chain ecosystem (Figure 3), where target is that information flows in all directions, analytics enabled through the supply chain and response is in real time. (Ferrantino, 2019)

2.2 Industry 4.0

Manufacturing has taken into new level, matter of the fact Industry 4.0 considered the fourth industry revolution (Figure 4). Journey from computerization and automation to cyber physical systems. Machines are communicating with each other and decisions are done based on the information what the machines are giving (Datapoint, 2018). Industry 4.0 goal is to have an intelligent network of products and process along the value chain. To have more efficient organized process, when creating goods and services to enhance the customer benefits. (Barreto. L, 2017)

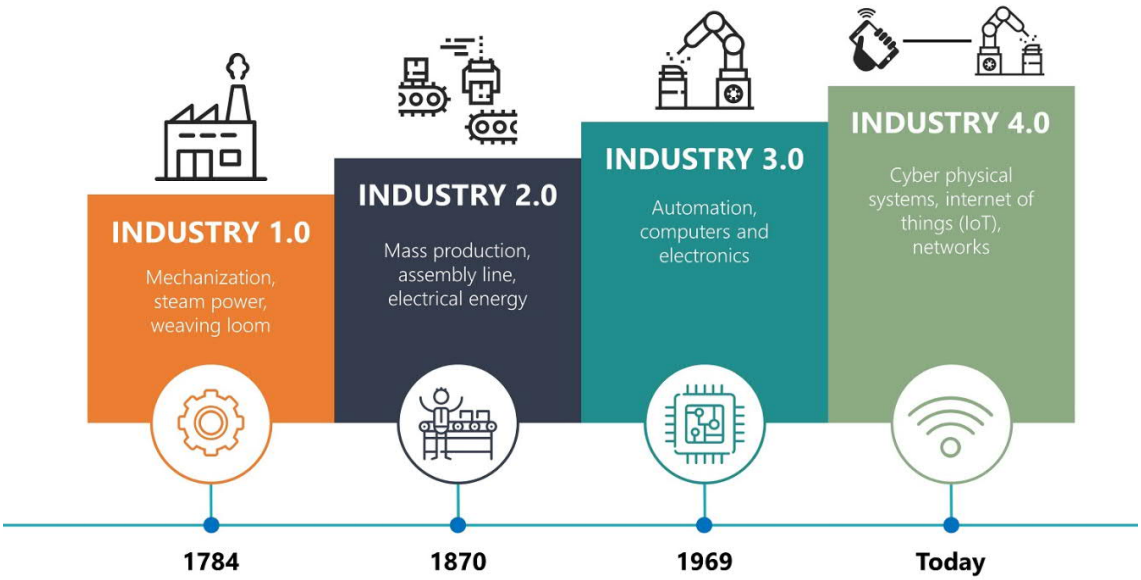

Figure 4. Industry 4.0 journey. (Datapoint, 2018)

Industry 4.0 is the emergency of digital manufacturing, also called as “Smart factory”, this means for smart networking, mobility, flexibility of industrial operations and integration between suppliers and customers. Intelligent networks based cyber-physical

systems (CPS) is unified to be part of the fourth industrial bigger change. CPS are engineered and physical systems, where you can monitor the operations, controlled, correspond, and combined by communication and data processing system. CPS contains cooperation with set of network agents and physical world. These networks agents can include example: sensors, actuators, process control unit and communication devices. Increasingly growth of wireless sensors which are embedded, and technological operations and the actuators has developed several applications more. These applications are mainly built to area: 'production processes, transportation system, logistics services, health services, autonomous vehicles, machine learning and smart structures, and consequently increasing technologies such as example Supervisory Control and Data Acquisition (SCADA) systems'. (Barreto. L, 2017)

The "Internet of Things" (IoT) is also recognized by "Industrial Internet of Things" (IIoT) has influenced how the CPS can collaborate, control, and handled. The collaboration between the processes and systems between technologies and contributing better cooperation and communication smart way, radical manufacturing, services, warehousing/logistics and planning resources more cost-efficient way.

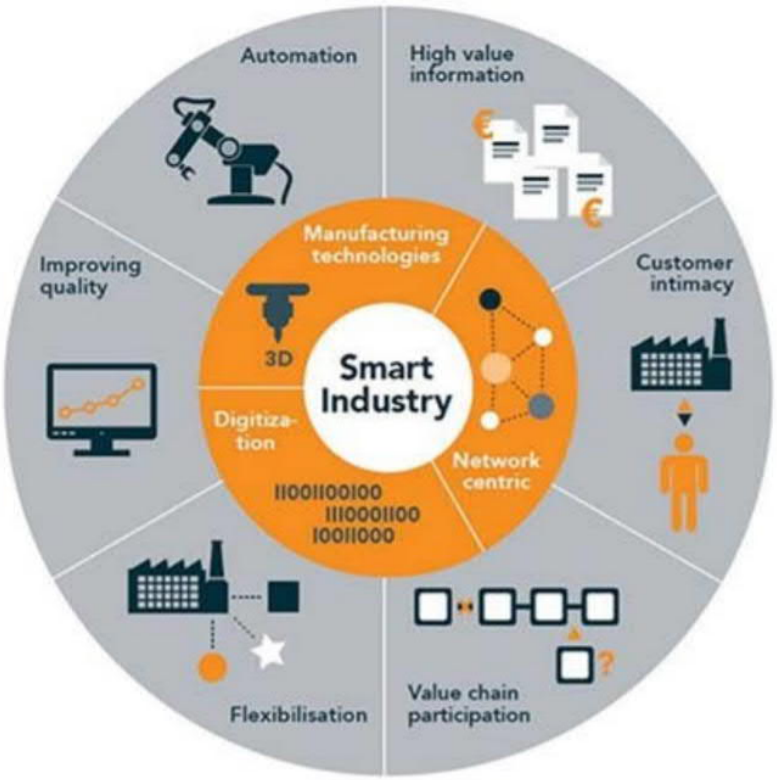

Figure 5. Industry 4.0 Concept**.** (Barreto. L, 2017)

To have a successful transformation implementation of Industry 4.0, there are fundamental technologies are needed to be part of the total system. In the Figure **5** is presented the industry 4.0 concept.

- Adaptive robotics. Different combination of microprocessors, AI methodologies, products, machines and services having a smarter capability computing, communicating, and controlling, but having also sociality and autonomy. General characteristic of the applications is example:
    - Ethernet or WLAN for high speed data transmission via Network
    - Easy integration between machinery communication systems
    - Part positioning with optical and image processing
    - Learning mechanism for memory or cased based
- Embedded systems (Cyber physical infrastructure). Embedded systems CPS is supportive technology for the coordination of network systems between physical infrastructure and computational capabilities. To achieve decentralized actions,

stand alone and digital tools should be connected with other devices. The embedded systems have properties to example condition monitoring with sensor less or with sensor, and then having feedback loop systematically and data should be integrated storage and analysed.

- Additive manufacturing is used for using technologies to produce products using digital models
- Cloud technologies are relevant topic for the input of networked system connection in transformation of Industry 4.0. The “cloud” term describes both cloud computing and cloud-based manufacturing and design. Manufacturing which is demand based the group of the resources in manufacturing for creating and operating re modify cyber-physical production processes. The requirements for the cloud-based solutions are example, the data driven applications has cloud-based infrastructure, and the supply network and user are integrated to the cloud system. Have a data analytics in real time for changes and notifications in process and take the full benefits optimize the big data function effiency in external and internal.
- Virtualization technologies are based Virtual reality (VR) and Augmented reality (AR) tools are computer supported reverse of real-world environment with all needed data and information. Could be said that virtual technologies have more beneficial and easier to user the interface design. Support is optimized through augment reality and gamification.
- Simulation. When creating the application new model, there should be have possibility to be simulated and tested the reflections carefully. Simulation can be used in manufactuirng development, optimization and test, process development, facility design and improvement. Industry 4.0 point of view simulation is a supporting tool for follow impact gathering various parameter changes and gives possibility for visualization when showing the results.
- Data analytics and artificial intelligence is used for having advanced information and knowledge technologies to manage their flow of the information, using the large number of real time data. The number of the data which is created during R&D, production, operations and maintenance processes is increasing in huge speed.

- Communication and networking are a link between distributed system and physical place and are independently defined. To achieve target tools, devices and machines used in communication, focus on integrating intelligent sensors in real environment and process. Industrial Internet of things (IIoT) needs both smart objects, smart networks and enables network integrated to physical objects.
- RFID and RTLS technologies. Nowadays smart factories have operations such as smart logistics, transportation and storages by securing efficiency between of integrated systems and information logistics. These operations include different operations, detect locations and monitoring conditions of resources and objects and RTLS and RFID enables real time data flow and high degree of data transparency.
- Cyber security. Industry 4.0 transformation demand lot of data collection and processing activities. To secure the data storage and transfer processes is fundament for companies. Security needs to cover both technologies in cloud, machines, robots and automated systems. There can be issues example: data entering, privacy management and make communication smoother, authorization for sharing data.
- Sensors and actuators are for integrated systems basic technology whole system including control installation, microcontroller and which monitors the actuators and sensors interacting the real world. The benefits with actuators and sensors are, that tracking real-time through the service and production chain.
- Mobile technologies have become more than normal communication tool. Devices like these make sure that can be connected to internet and can handle large amount of data/information and contains communication equipment’s like high quality camera and microphones transmit information. (Ustundag, 2018, pp. 5-17)

3 ERP SAP system in Supply Chain

This chapter is for introduce the ERP system from SAP, what the SAP ERP is and what is the core businesses is included. The target in this master thesis is to have overall picture of the SAP ERP for supply chain from: supply chain, to warehousing and manufacturing.

An ERP system is made for enterprise resource planning activities which share the database communicates between the processes. The system gives for user a single source information and can eliminate information data between organizations. The ERP system is to replace the internet applications and separated systems which can communicate together. The ground of ERP system is common database through the processes generally in areas: finance, human resources, controlling, sales, production planning, logistics, material management and manufacturing. 1 (SAP, 2019).

3.1 SAP S/4HANA

The objectives for this chapter are to understand the three main drivers for SAP S/4HANA, which are: the database technology, business process improvements, and IT flexibility. How these three drivers for the business benefits in SAP S/4HANA.

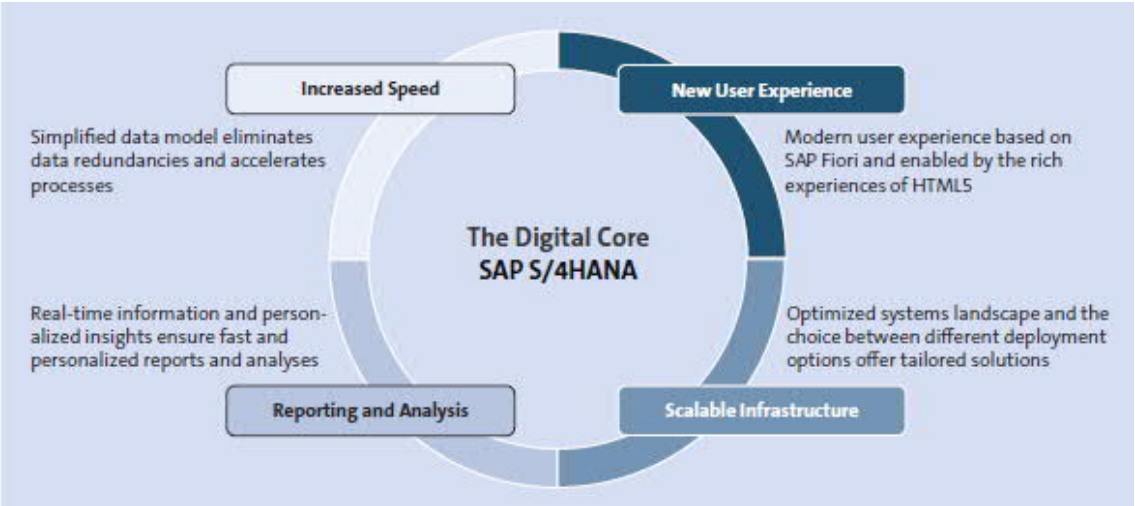

Figure 6. SAP S/4HANA value drivers. (Bhattacharjee, et al., 2018)

SAP S/4HANA core (Figure **6**) gives possibility to scale your transformation across the entire enterprise. SAP S/4HANA is a technical solution as an end solution, which are consist of the platform and database, SAP Fiori app possibility. SAP Fiori will be presented more deeper in chapter 3.1.2. SAP S/4HANA is a database system, which designed to speed up accesses for reading data, not slowing data insertion. In Figure **7** is presented how the S/4HANA capabilities are structured in commercial point of view. S/4HANA enterprise management represents the core solution and covered business processes and marked in the Figure **7** as a dark grey area in the middle cross the main processes: Sales & marketing, finance, manufacturing, supply chain, service, asset management, R&D / engineering, sourcing & procurement and human resources. S/4HANA Lines of Business (LoB) and suite lines of business are solutions, which can be activated as embedded one solution. These can be activated investing the separate license. (Cusack, 2019). In this master thesis the focus is on the manufacturing and supply chain processes and functionalities, and in the chapter 3.1.2 will be opened in more details the core functionalities of these process steps.

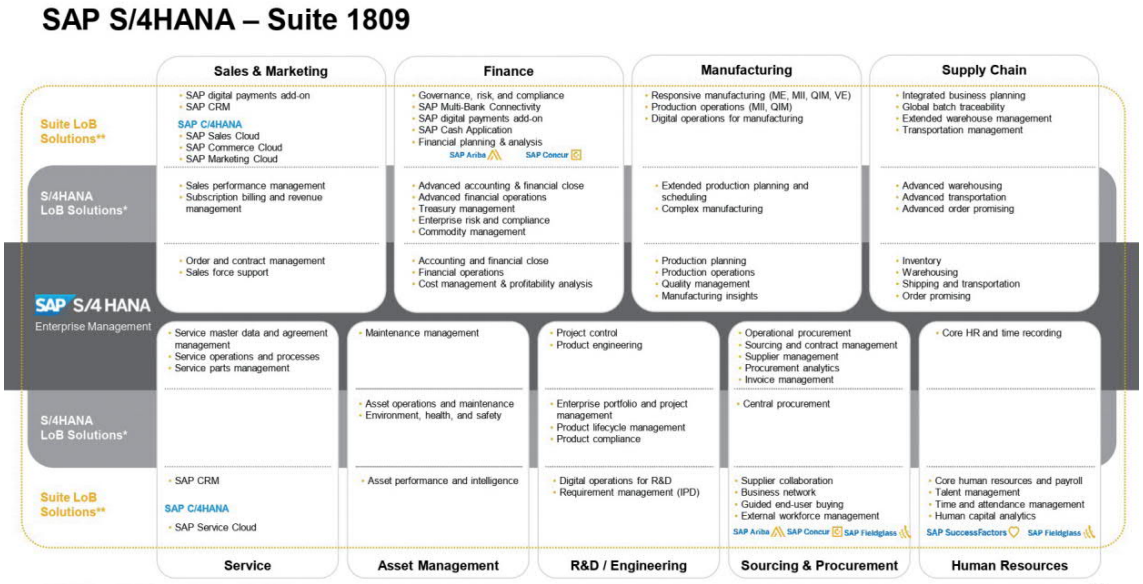

Figure 7. SAP S/4HANA: - Suite 1809 (Cusack, 2019)

SAP S/HANA has been made for provide next-generation processes that is connected and possibility to orchestrate entire business and gives for employee's smarter tool to make decisions using artificial intelligence. Listed out the benefits from the S/4HANA platform:

- For digital world the new digital core solution
- Real time analytics on transactional data
- Complete flexibility in reporting using external hierarchies
- View referencing capability
- Streamline the business processes
- Better user interface
- New business processes for customer interaction and customer service
- Faster MRP runs
- Predictive analytics and simulations
- Better integration with other applications
- Flexibility when changing reporting structures
- Real time simulation of business scenarios
- Reduce the cost of maintenance
- Deployment of extensions in HCP (SAP, 2019)

3.1.1 Data Model Simplification

SAP has re-engineered the SAP S/4HANA platform to have maximum in-memory capability of database. Target is with S/4HANA to simplicity in transaction, advanced

analytics, innovation and enhance the functionality compared to older SAP ERP system. (YARD, 2018)

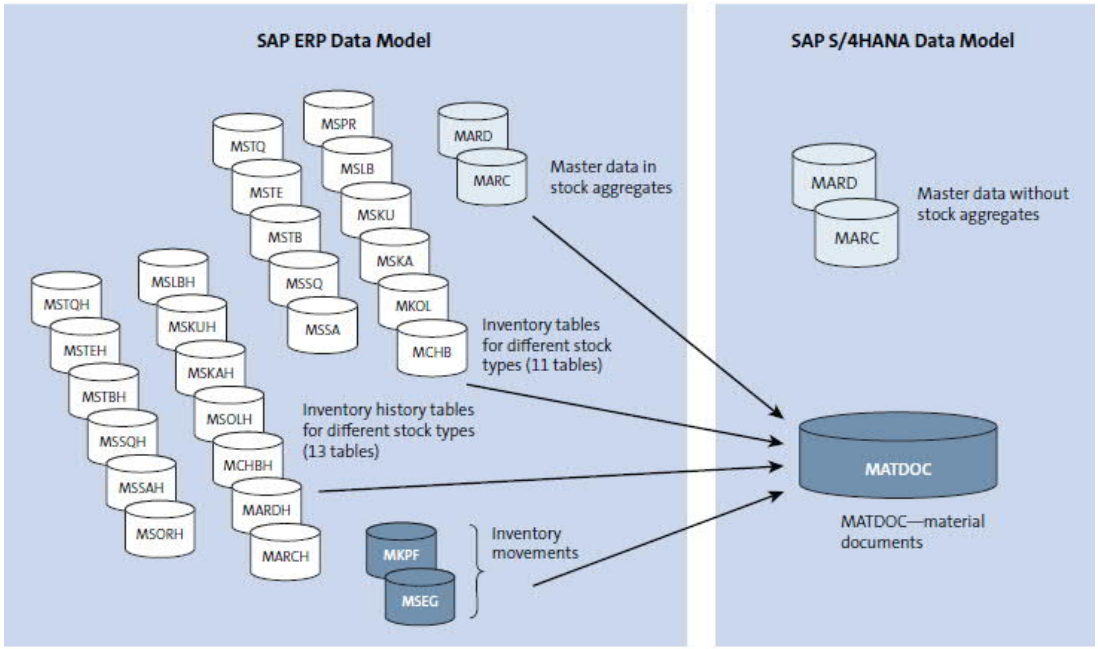

Figure 8. Data model design for inventory management. (Bardan, 2018)

The benefit of the SAP S/4HANA simplified data model change is a significant decrease in aggregated and history tables as in Figure 8 is presented as example of inventory management and in Figure 9. Improvements of simplified data model is increased throughput, better and faster reporting when most of the information is coming from one table, more flexible design when no additional tables. In SAP S/4HANA customer coding needs to be evaluated and adjusted per need. (Bardan, 2018)

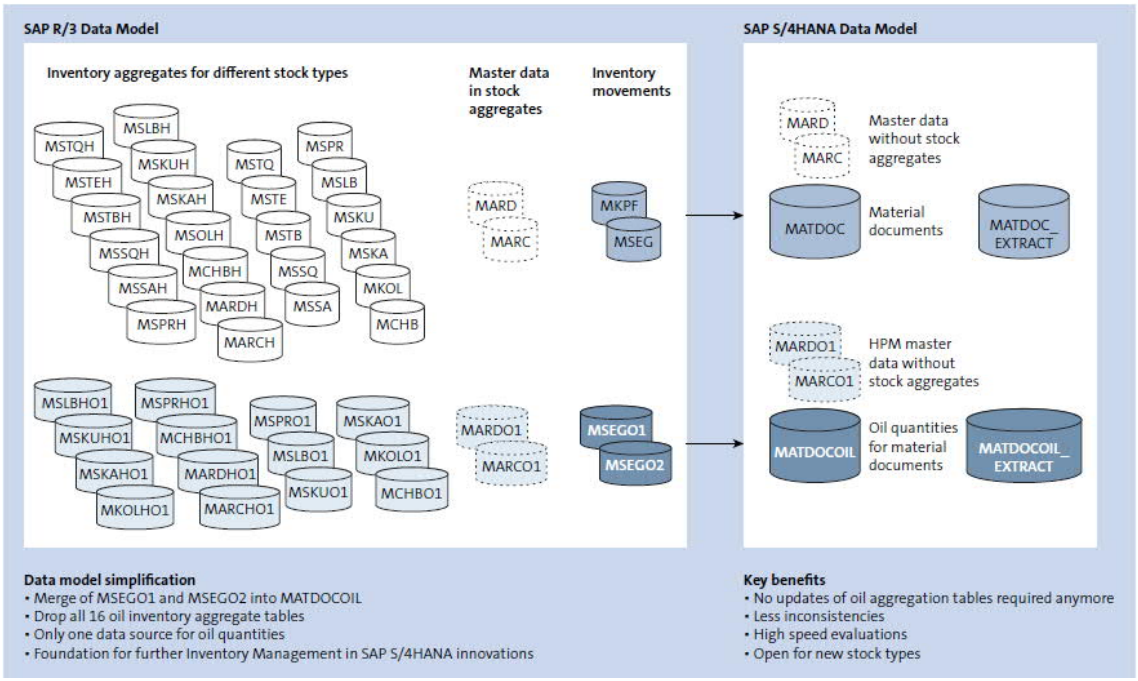

Figure 9. Data model simplification. (Bardan, 2018)

3.1.2 Fiori

Business has changed more flexible and adaptive and companies complain the old-fashioned standard desktop and computer. SAP made development and created applications based on the HTML5 framework included the widely and commonly used SAP transactions, example purchase order and sales order creation. HTML5 created applications are easy to access, and can be used across desktops, tablets and smartphones. (Mathew, 2015)

Fiori was developed a flat user interface on the HTML5 framework and emphasis UI apps. In Figure **10** is presented the Fiori launchpad. It was developed based on the design principles: role-based, responsive, simple, coherent and instant value.

- Role-based means that each app created is specified to a user role. User can have multiple roles and UI can be developed for specific task which belongs to different SAP modules. UI can be also been visualized for specific user environment to support different needs.

- Responsive for seamless across screen sizes and different devices but requires HTML5-compatible browser. Fiori works independently of platform example windows, android or iOS. Also support interactions modes, keyboard, touch based inputs and mice.
- Simple user interface helps operate quickly and easily. Fiori apps has emphasized approach like 1:1:3, which means that one user, one use case, and three screens. Screens can be desktop, tablet and mobile.
- Coherent system to use, when every Fiori app speaks the same design language, so after using one Fiori app user feels comfortable with other Fiori apps.
- Instant values can be keeping the training users in the new UI. The UI is generally easy, simple and follows the same design pattern across apps. (Mathew, 2015)

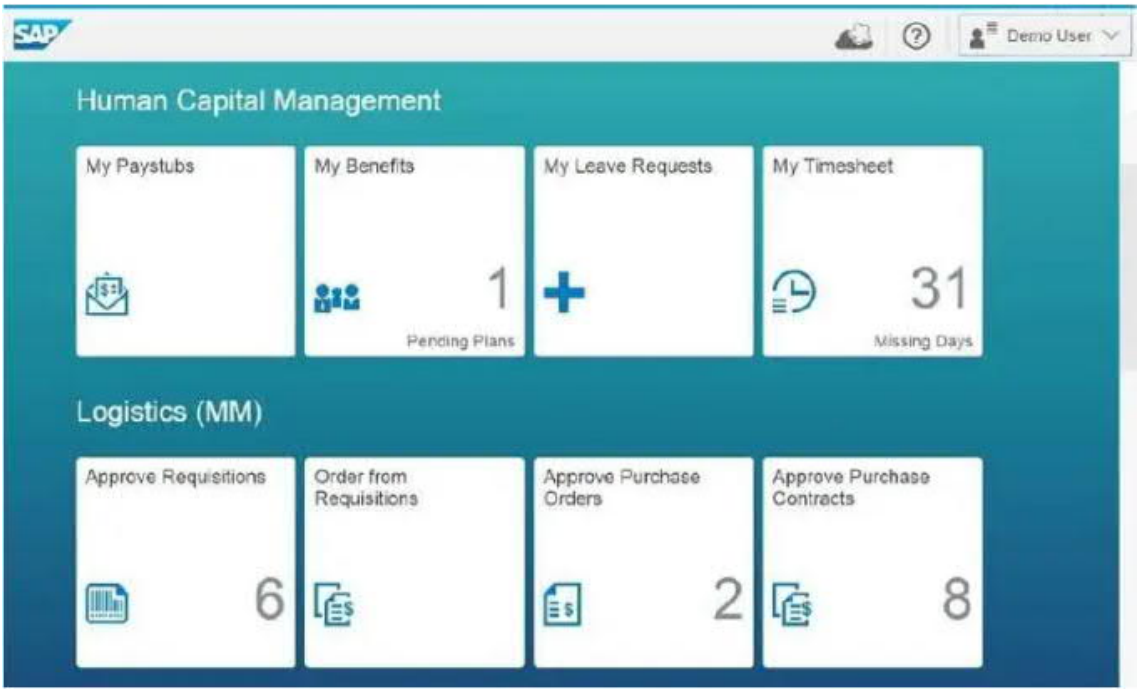

Figure 10. Fiori launchpad. (Mathew, 2015).

Fiori transactional applications supports the S/4HANA database and traditional databases that SAP ERP supports. The architecture for the Fiori is presented in Figure 11 as a generic overview how the Fiori applications are deployed and how the end user is

consuming. The Fiori can be used with different devices example desktops, tablets and mobile devices. When the user accesses the Fiori applications first time, it will be downloaded to web browser. The ABAP front-end server contains the layer of UI, which has the product-specific UI components created for Fiori applications. (Mathew, 2015)

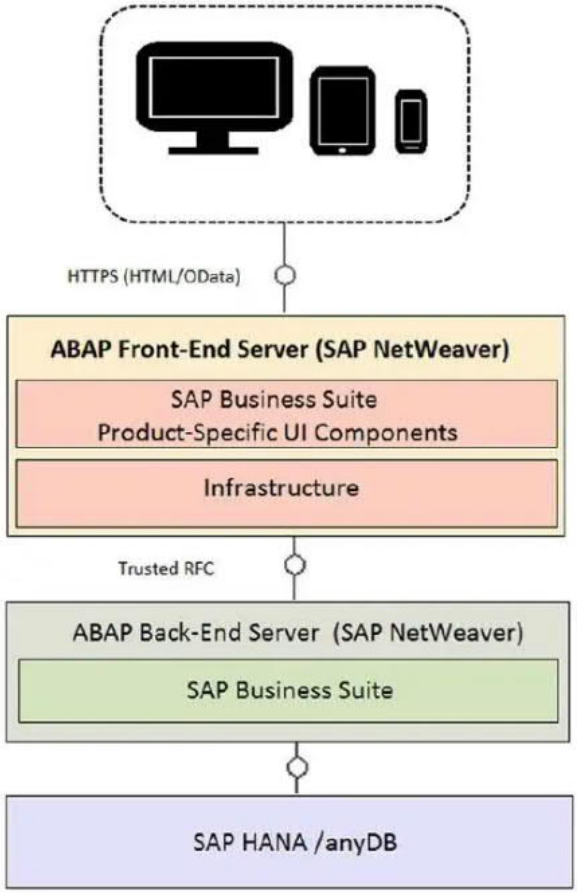

Figure 11. Transactional application architecture for Fiori. (Mathew, 2015)

4 RESEARCH METHOD AND CASE COMPANY

The purpose of this chapter is to present the chosen methodology of the study and specify selected research questions. The chapter contains the defined research method company presentation, research design and analysis of the data. The case study validity and reliability are evaluated also in this chapter.

4.1 Research Method

The ways how to collect and process the data, determines what kind of information can be produced. Certain type of information requires a certain kind of research method. The research method can be different scientific traditions and approaches in several different methodologies and way to do the research (Olkkonen, 1994, p. 50.). Tradition has a usually typical structure and typical research methods, but the research question should define the used method and data in the study. (Yin, 2009, pp. 8-11.)

When designing the research method for the study, there are two categories of research methods. These two are: *quantitative* and *qualitative* method. The qualitative methodology is positivism research and the quantitative research methodology is on hermeneutic research. (Olkkonen, 1994, p. 50.)

The p*ositivism* is based on exclusively identified and verifiable observations. Positivism target is to find out on the abstract level the conflicts between the realities. The positivism research method can be divided into two research: inductive- empirical research and theoretic research. The inductive- empirical research method follow with the empirical scientific model, and mathematical probability is to verification the results. The theoretical research is to extrapolate theories and to create/develop new theories using the existing ones. Inference is inductive, deductive or abductive. Deductive inference is challenging existing theories empirically. Inference is inductive, is study has approach above the empirical findings and creates hypotheses. When the hypotheses have received a scientific finding, they can be created and generated to theories. The research is abductive, if the existing theory is tested and be presented in the empirical part at the

same time. This leads to create new assumptions in the theory form. The case study is independent from the researcher and is repeatable then it is positivism. Result is same if another researcher uses the same material and same methods. (Olkkonen, 1994, pp. 35, 50 – 52.)

When the statistical findings data is not possible to analyse, *the Hermeneutic* approach is to understand the inner connections and the process changes on the target environment. Comparing the hermeneutic and positivism method, the hermeneutic are as an inner study. Hermeneutic study cannot be guaranteed that the research is independent and reliable, because the data is discovered through the researcher`s own understanding and knowledge. (Olkkonen, 1994, pp. 35, 39, 52 – 53.)

To define what the used research method and data is, the research objectives have been set into research questions. The purpose of the study was to understand from the empirical point of view the existing theories and findings and results. The theoretical deductive research method was the most suitable for the study purpose. The research questions were defined that the questions can explain the empirical findings and compare then to the existing theory. The purpose in this case study was to: *investigate how real-time optimized supply chain management could support meeting the variable manufacturing unit demand by creating smart supply chain that supports the demand-driven value chain.*

The research questions in this case study were formulated accordingly as follows as mentioned in the beginning:

RQ 1: What future capabilities of SAP S/4HANA could support manufacturing material flow / logistics in case company?

RQ 2: How the supporting supply chain solutions of the extended functionalities in SAP S/4HANA is giving benefits for case company?

The reasoning in the study is based on existing theories of the SAP system from general knowledge compared to company background. The study uses the deductive approach to be answering to the research questions defined through existing theories which are link to the empirical part of the study. Theory is the support of the empirical data analysis in the study.

4.2 Research Design and Analysis of the Data

The case study was chosen as a research method, based on the research methods that was analysed before. A research case study can be divided into four different categories, when designing the case study research. In Figure 12 is presented four types of design and divided in to 2 x 2 matrix. The matrix presents that single and multiple case studies are reflecting to different design situations. Single- case holistic design, single-case embedded design, and multiple-case holistic design, multiple-case embedded design are the four types of designing case study. (Yin, 2009, p. 47)

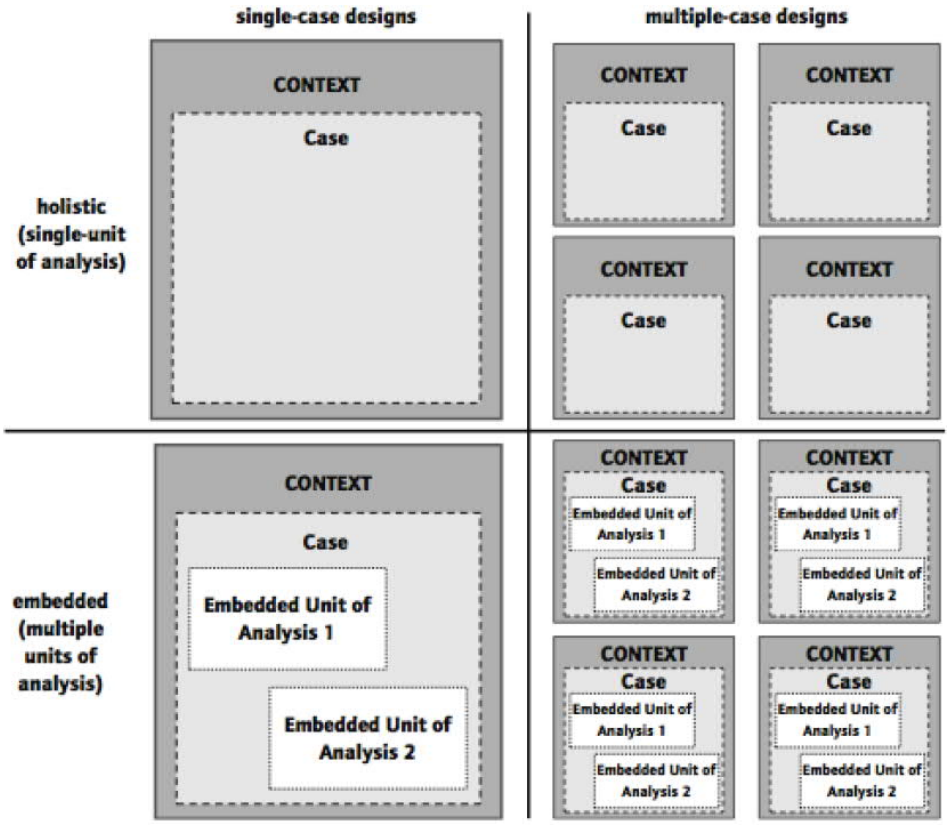

Figure 12. Basic types of design for case studies (Yin, 2009, p. 46).

The selected and used research method for this case study is an embedded single-case design. The reason for selecting the embedded single-case design is that even the SAP S/4HANA is divided and affects to several business processes, the system itself is single case. The approach for the study is to research capabilities from SAP S/4HANA to the case company.

The reason using embedded multiple units of analysis instead of holistic single unit of analysis is because the study is a single implementation project, but there are several modules in SAP S/4HANA portfolio for different business process which are considered in this study. If there were only effects on one single business process, the method it would be holistic.

Data collection is divided into primary and secondary data to support and resolve the research questions. The **secondary data** was collected from data and the documentation of sales material related to SAP S/4HANA, and the author's knowledge after working years with SAP ECC. The **primary data** was collected to find out answer to the questions which was not covered on the secondary data. The subject meetings target was to deepen researcher's understanding of the research scope and try to find out if the primary data collection supports the secondary data. The primary data has been collected focusing on the warehouse management capabilities. The data were collected by researching the data from system capabilities and having interview meeting with process specialist to find out the needs compared to current system in different process step. The main focus in meetings was to have a discussion of SAP S/4HANA in general level, and to find out the future capabilities on supply chain process perspective.

The secondary data and primary data are divided into categories as described in table 1.

Table 1. Data Collection in thesis

Data structure	**Data collection**
Secondary data	• Current SAP version versus the coming upgrade • Project user requirements for SAP S/4HANA • Estimated scope of the project • SAP S/4HANA assessment for the case company
Primary data	• In-Depth meetings and data • Data analysis for find out the future capabilities

4.3 Validity and Reliability of the Study

In this chapter the focus is to understand whether the case study method and the collected data are valid and if the results are reliable. The quality of the study needs to be identified clearly, the two factors needs to be considered: reliability and importance of the study.

Validity consist the experimental concept and establishes if the research results reaches all the requirements of the research method. The validity of research can be divided to three categories which points out the specific methodological question contract validity, internal validity and external validity. (Yin, 2009, pp. 40-42). Methodological limitations in this case study are theoretical framework, selected workshop participants, selection of the structured in-dept meetings. In addition, there might be influence the assumed objectivity towards the response due to my role as member of the workshop and be colleague to the workshop participants.

Construct validity is an assessment where actual measurements are selected from theories. When using multiple sources of the references and in-dept meetings construct validity improves. However, in this study the construct validity can be argued to meet requirements, when there is link between both theoretical and empirical part is in place. In this study construct validity increases by the communication and research meetings. How to challenge the construct validity is to understand how well the selected measurements and meter measure what should be in this case study. (Yin, 2009, pp. 41-42). In this the author believes in the measures, because of the wide collected data and support of different organization structure.

Internal and external validity. Internal validity is based on the how well the chosen metrics covers the research case. This means that how well in research case chosen metrics covers phenomenon rather than how relevant the meter is with theory. (Yin, 2009, pp. 42-43). Externa validity covers that if the research findings are generalizable across the immediate research case. (Yin, 2009, pp. 43-44). External validity in this research is difficult to point out, because the study focuses on one case company context and the others are not so much accounted. All the results are linked into the case company data and resolve the functional benefits in this case company. However, in the study are raised up important general topics which can be noticed in the other companies, if taking the industry and overall company context into account. When scope of the research is quite

wide, the influence on the reasonability can be found in the conclusion. When the implementation to the SAP S/4HANA starts is increases the validity of study.

The reliability of the research study needs to be understood correctly, can research be replicated in future in the case company. As Yin stated (Yin, 2009) that if the later investigator researches the same protocol and will do the same case study again, the conclusion should be that there is the same findings and conclusions. In this study the reliability can be separated into two main things. Firstly, if the research were done at the same time by some other researcher, the results could be different if the data would be coming from different process experts. The time context place huge role in results, the exact same topic and scope would not be possible to do, because when implementing SAP S/4HANA the processes are changed the future needs. However, the reliability of the study can be measured by having lessons learnt event after the deeper assessment and implementation phase.

4.4 The Case Company

The case company is presented in here briefly and on a common level, because the company want to stay anonymous. This mean that many delicate information and results of the business unit in this study cannot be presented. In general level empirical findings of the study can be presented.

The chosen case company is an industrial manufacturing company and operating in heavy industry environment manufacturing field in Finland. The company is part of a multinational corporation which has operations around the world. The business unit was selected in the study by a need of project support and wider research to authenticate the business need.

5 RESEARCH PROCESS AND RESULTS

In this chapter the SAP S/4HANA supply chain functionalities is presented in more detail, its background and its benefits. This chapter answers to the research questions: *What future capabilities of SAP S/4HANA could support manufacturing material flow / logistics in case company?* and the second research question is: *How the supporting supply chain solutions of the extended functionalities in SAP S/4HANA is giving benefits for case company.* The outputs of research were open source material and in-depth meetings with ERP architect and SAP company.

5.1 SAP S/4HANA for the Supply Chain

This chapter is for introduce the SAP S/4HANA supply chain/ procurement process today's enterprises, what are boundaries between supply chain with an SAP cloud system such as integrated business planning, production planning and detail scheduling, SAP Ariba, extended warehouse management, transportation management and manufacturing. (Ashlock, 2018). In Figure **13** is presented the simplified supply chain model in SAP S/4HANA.

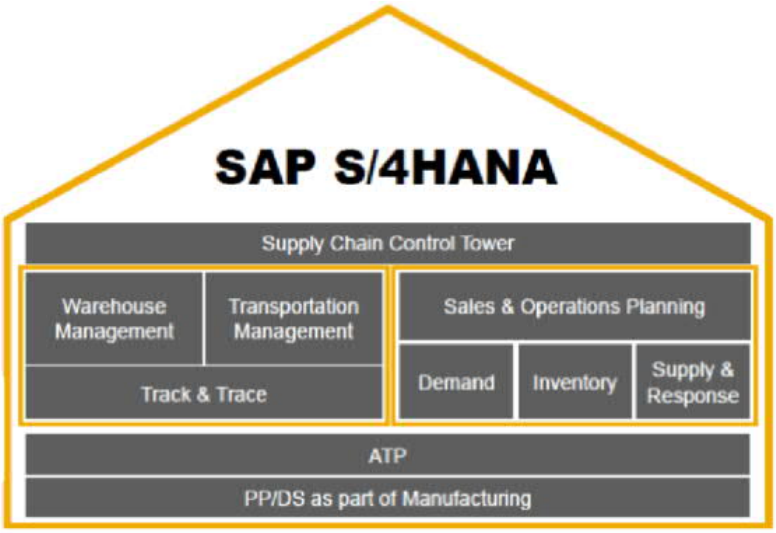

Figure 13. Simplified supply chain embedded in SAP S/4HANA. (Manna, 2015)

5.1.1 Integrated business planning (IBP)

Integrated business planning (IBP) is advanced supply chain planning from SAP, which includes applications:

- Sales and operations planning
- Demand planning
- Response and supply planning
- Inventory management
- Supply chain control tower

Sales and operations planning allow organization work together as an integrated team for one plan product, demand and supply, between suppliers, production plants, warehouses, distribution centres, and other stock and facilities. This gives the possibility to have a central place where comes together demand, supply and financial plan. (Markin & Sinha, 2017). In Figure 14 is presented how the SAP sees the planning summer in SAP S/4HANA.

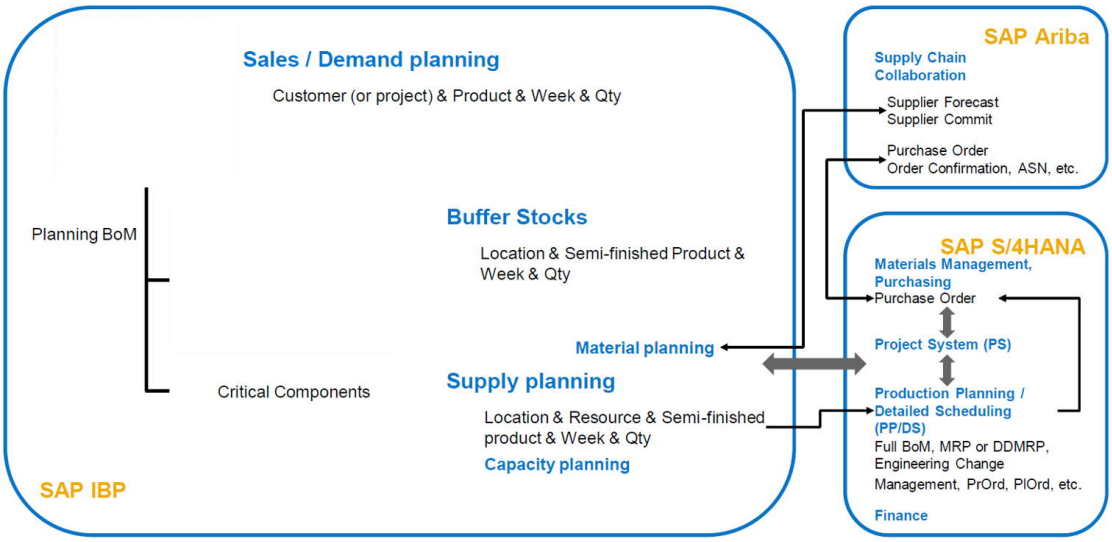

Figure 14. Planning summary in SAP S/4HANA. (SAP company material, presented for case company)

SAP IBP provides for demand planning capabilities for forecasting demand in short-term, medium-term and long-term horizon. Using the historical data and a statistical

forecasting, gives possibility for the full planning. SAP IBP for demand capabilities has been developed with the advanced predictive analytics, demand sensing and enhanced planning capabilities. Modelling the forecast enables there are capabilities to have several combinations of statistical models to predict the forecast. 'Predictive analytics have autoregressive capabilities to identify the best fit model along with the relevant parameters of the forecast algorithm' (Markin & Sinha, 2017).

Response and supply planning can be divided to short-term, medium-term and long-term planning horizon. Supply planning special focus on the medium-term planning horizon, to meet requirement from customer demand, sales order and internal consumption. Supply planning in the long-term is aligned with sales and operations planning, and the short -term planning works with response planning. Response planning is concentrating reacting to market changes in the short term by creating desirable results. If there is lot of variation of the actual event the anticipated behaviour requires a response management solution. The real demand can vary from the forecast, example the supplier has challenges to supply components or there will be transportation delay, it can disrupt the supply plan. Response planning is a supply chain solution for short term planning to enable effective responses. (Markin & Sinha, 2017, pp. 251-252). Long-term supply planning is performed normally in between 18 months to 5 years range and typically in monthly horizon. This support for the strategic decisions of the demand and supply, for making decisions regarding product development, capacity enhancement, supplier selection and network planning. (Markin & Sinha, 2017)

Inventory management in the integrated business planning addresses optimal level of inventory investment across supply chain to have higher level service. Inventory needs to be optimized by calculated, and one way is to categorize the inventory. Inventory can be divided into two categories in the supply chain network: product based and inventory optimization calculations. These are used to support product movements, material storage and inventory planning. (Markin & Sinha, 2017)

Supply chain control tower has been designed to understand if decision that has been made is fact have the desired effect and how to improve them in the next planning cycle. Supply chain control tower gives possibility to have visibility across the organisation, even from outside the company to be combined planning data to provide end-to-end view

of the digital supply chain. SAP supply chain control tower solution has been designed to be conjunction to the other integrated business planning applications as a common analytics solution. Figure 15. SAP Integrated business planning landscape. Figure 15. SAP Integrated business planning landscape. Figure 15 presents the SAP integrated planning solution landscape with other earlier presented solution in this chapter. (Markin & Sinha, 2017)

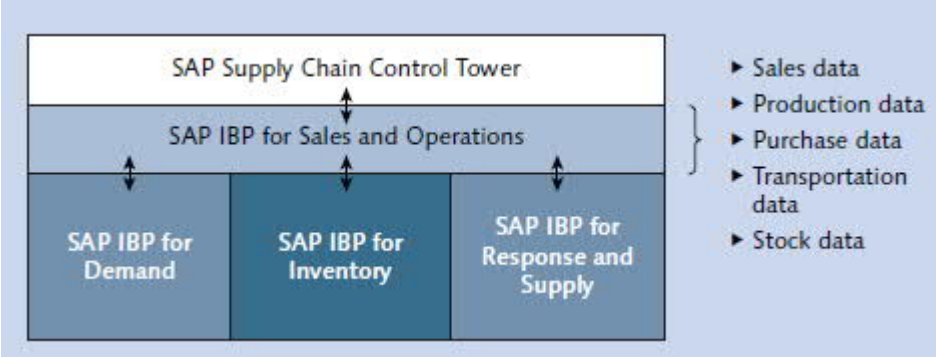

Figure 15. SAP Integrated business planning landscape. (Markin & Sinha, 2017)

To support hole chain the SAP IBP and SAP supply chain control tower has capable to connect to the operational system to give transparency information to supply chain execution. These operational systems include: order execution, purchasing, transportation and other supply chain relevant information. (Markin & Sinha, 2017)

5.1.2 Production planning and detail scheduling (PP/DS)

Business has become more complex with different scenarios and there are challenges to have planning in global environment, there for SAP has developed more advanced tool for planning. In supply chain management (SAP SCM) there is a product called SAP advanced planning and optimization. Advanced planning and optimization include several modules which are: complex and advanced supply chain planning, demand planning, supply network planning, production planning and detail scheduling.

Production planning and detail scheduling will be presented in this chapter in more details. (Almeida & MG, 2018)

SAP advanced planning and optimization's PP/DS functionalities compared to SAP ERP the structure is similar, but PP/DS provides capabilities which are not in SAP ERP. Those are example: material planning with limited capacity planning, planning with specific times, forecast consumption with fitting characteristics, planning with multiple levels/steps, assign dynamically elements across bill of material (BOM) and planning with algorithm which executes the planning on selected objects. (Almeida & MG, 2018)

PP/DS has production data structure, which includes the routing and BOMs which are used for materials and capacity planning. PP/DS provides advanced tools and features in SAP S/4HANA example:

- Material planning including the finite capacity planning
- Planning with defined exact times
- Forecast consumption using the descriptive characteristics
- Running the planning with multiple steps
- Dynamic assignment of receipt elements together across the BOM
- Planning with algorithm that executes selected objects on the planning. (Almeida & MG, 2018)

One of the key changes in the embedded PP/DS has a feature to harmonization of the master data. Master data or work center data creates automatically for the PP/DS the product master or resource data. There is not anymore need to create integration model or production data structure when creating the sources of supply. MRP live gives possibility to have in-memory planning runs and has possibility to do planning heuristic. (Almeida & MG, 2018).

5.1.3 Supply chain collaboration with Ariba

SAP Ariba is cloud platform for enabling enterprise to carry out the entire source to pay process and to support organizations control costs, improve profits and minimize risks. Source system for providing master data for the SAP Ariba is SAP S/4HANA, and vice

versa real time transactional data/documents such as purchase orders, goods receipts, and contracts is replicated from SAP Ariba to SAP S/4HANA. SAP Ariba includes has the following solution components:

- Ariba network
- SAP Ariba strategic sourcing
- SAP Ariba procurement content

Ariba network gives possibility to buyer and supplier to work together efficiently to manage business processes. Buyer has possibility to purchase orders electronically with Ariba network, and supplier can exchange order confirmations and advance shipping notification (ASN). Key capabilities for Ariba network are electronic invoices, collaboration and compliance. Ariba network has following benefits:

- Can be integrated with any SAP ERP protocols and backend
- Supports the exchange for the documents for goods and services
- To reduce the invoice error in accounts payable functions there is transaction rules help to validate invoice errors

SAP Ariba strategic sourcing includes: sourcing, contract management, and spend analysis, and for these there is following solution components:

- SAP Ariba Sourcing
- SAP Ariba Contract management
- SAP Ariba supplier performance management
- SAP Ariba spend analysis
- SAP Ariba discovery

SAP Ariba procurement content includes the operational procurement activities. Ariba procurement content contains these solution components:

- SAP Ariba buying, advanced edition
- SAP Ariba buying edition
- SAP Ariba catalog
- SAP Ariba invoice management

SAP S/ Hana provides integrations to Ariba Network between buyers and suppliers to have effectively collaborate. Document data exchange between SAP Ariba and SAP S/4HANA occurs through commerce Extensible Markup Language. The Figure 16 presents the standard integration between S/4HANA and SAP Ariba.

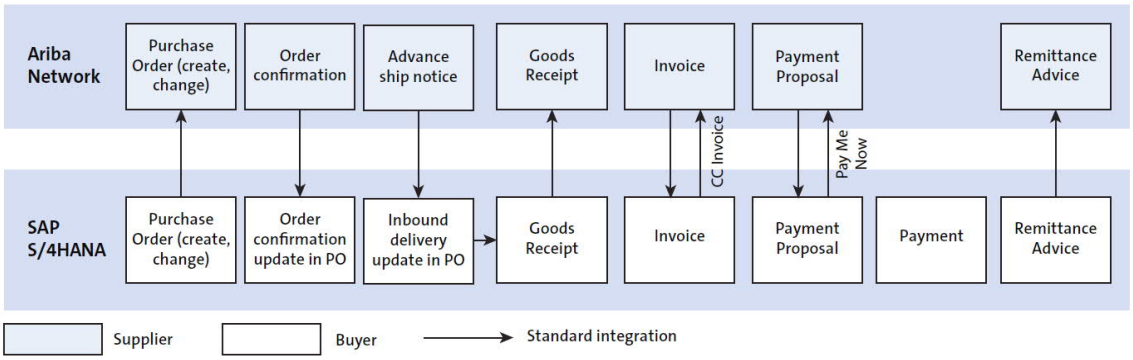

Figure 16. SAP S/4HANA and SAP Ariba Standard Integration. (Bhattacharjee, et al., 2018)

5.1.4 Extended Warehouse Management (EWM)

SAP warehouse management focuses on providing inventory accuracy, optimizing the utilization of warehouse space and streamlined picking and putaway. In 1993 SAP launched the SAP ERP Warehouse Management (WM), which is the submodule of the Materials Management (MM). WM solution supports the storage units, has a warehouse monitoring, HR integration, radio frequency (RF), decentralized WM, and task and resource management. In 2005 SAP had release for version 5.0 in the SAP Supply Chain Management (SCM) software, and the version included the SAP Extended Warehouse Management (EWM). SAP EWM architecture design focuses on the needs of high volume, automated and complex warehouses.

SAP EWM in SAP S/4HANA is supporting extensive of warehouse complexities. EWM can be divided to warehousing which is the digital core, advanced warehousing and SAP S/4HANA supply chain. Here listed the high-level functionalities on these categories, which gives possibility to optimize warehouse operation and transparency and control for warehouse.

Warehousing the digital core:

- Inventory Management
- Inbound Processing
- Outbound Processing (Incl. change deliveries)
- Internal Warehouse Movements
- Physical Inventory
- Reporting
- Enhanced QM Integration in S/4HANA with EWM
- New Pick-by-Cart Fiori App

Advanced warehousing:

- Inventory Management Optimizing (e.g. slotting)
- Inbound Process Optimization (e.g. deconsolidation)
- Outbound process optimization (e.g. waves)
- Material flow control
- Yard management (e.g. TU handling, DAS)
- Labour Management (incl. process, shifts, time & attendance, travel, distance, standards, tracking and monitoring)
- Value added services
- Kitting
- Cross docking
- Warehouse billing
- Integrated load planning
- Improved package builder & stock consolidation

Decentral SAP EWM:

- High volume warehouses
- Independent operations, versioning, upgrades
- Material flow system (MFS) (Blogs, 2018)

Functionality	SAP Warehouse Management (WM)	SAP EWM
Manage Stock at Storage Location	☑	☑
Warehouse Bin Management	☑	☑
Placement Strategies	☑	☑
Removal Strategies	☑	☑
Pick Logic	☑	☑
Replenishment	☑	☑
Standard Mobile RF Technology	☑	☑
Storage Unit Management	☑	☑
Handling Unit Management	☑	☑
Yard Management	☑	☑
Enhanced Configurable RF Technologies		☑
Task & Resource Management		☑
Expected Goods Receipt		☑
Value Added Services		☑
Opportunistic Cross Docking		☑
Dynamic Cycle Counting		☑
Unloading/Loading of Transportation Units		☑
Deconsolidation		☑
Slotting & Re-Arrangements		☑
Labour Management		☑
Task Interleaving		☑
Standard Voice Picking		☑
Standard Material Flow System Integration		☑
Analytics Enablement		☑
Standard Integration with SAP TMS		☑
Standard Dock Appointment Scheduling		☑
Standard Weigh Scale Integration		☑

Figure 17. Capability comparison of SAP SCM EWM 9.0 with SAP ECC-WM based on SAP ECC 6.0. (Patabendige, 2013)

In the Figure 17. Capability comparison of SAP SCM EWM 9.0 with SAP ECC-WM based on SAP ECC 6.0. is comparison between SAP WM and EWM. In future the SAP EWM in SAP HANA gives possibility to better performance in processing, handling large volumes of data and has capabilities for predictive analytics. Also, to have comprehensive, transparent and flexible automated process is supported in EWM. It has been developed to support high performance, high volume warehouse operations in medium and large-sized warehouses.

SAP EWM is more flexible and provides advanced warehouse functionalities. Embedded and decentralized SAP EWM are structured same way. Compared to SAP WM the structural elements of the warehouse and master data are structured

similar way. Figure 18. Extended Warehouse Management in structural point of view. shows that how the SAP EMW is divided hierarchically. (K.Roy, 2018)

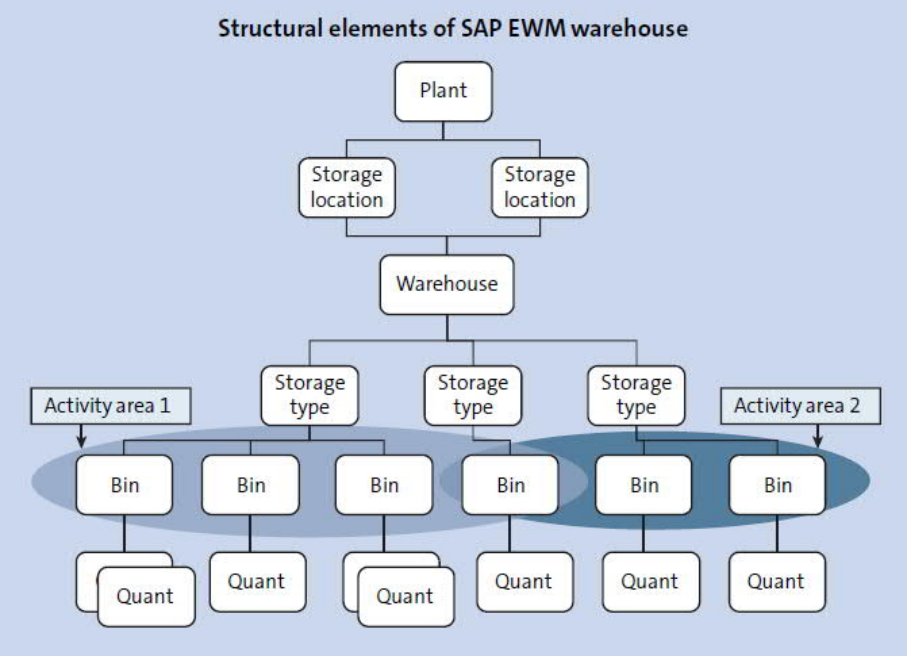

Figure 18. Extended Warehouse Management in structural point of view. (K.Roy, 2018)

SAP EWM implementation one of important task is to map physical warehouse layout with using the structural elements. Important elements to map a warehouse layout are:

- Warehouse no.
- Storage type
- Storage section
- Storage bin (K.Roy, 2018)

5.1.5 Transportation Management

Transportation is generally term for moving goods, form shippers or pick-up point to consignees or drop-off point. Shipment is also end-to-end move goods being handled

together, and movements of shipment can be various stages and using multiple modes of transport, example ocean, air, road, or rail. Transportation management is then ability for coordinate the transportation process. The SAP transportation management in SAP S/4HANA includes shipping functionalities. Shipping functionalities are transportation planning, inbound shipment management, outbound shipment management, transportation execution, shipment cost processing, shipment monitoring and tendering of the service agents. With SAP transportation management functionality can manage functionalities example: transportation scheduling, vehicle scheduling activities, strategic weight management, transportation management for inbound and outbound stock, billing for carrier ad service, vehicle scheduling and process for shippers. (Sauer. S, 2018)

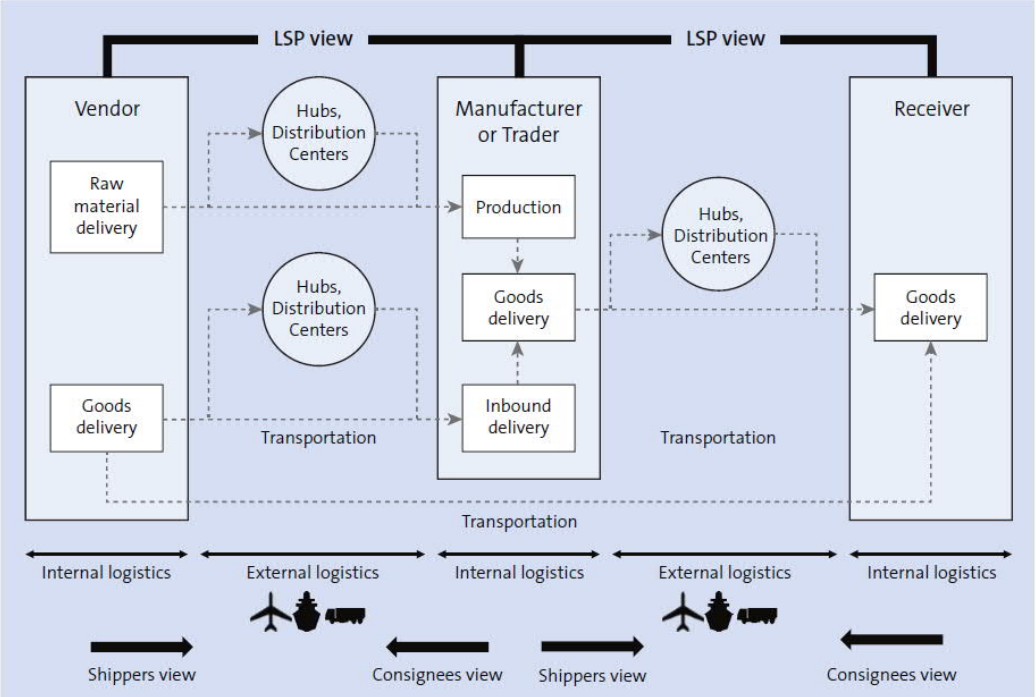

Figure 19. Transportation management process and view of shippers, consignees and logistics service providers. (Sauer. S, 2018)

Transportation management (TM) in SAP S/4HANA suite contains functionalities which are far away from transportation processes. Transportation process is presented in Figure 19. Here is listed directly transportation related SAP S/4HANA functionalities/components:

- Transportation management
- Warehousing, basic inventory and transportation
- Advanced inventory, warehousing and transportation

And here is the list of components which are integrated:

- Operational purchasing
- Contract and order management
- Product safety and stewardship
- Risk, compliance and governance (Sauer. S, 2018)

Differences between the sales, purchasing and transportation process. The transportation process is not executed directly on delivery document or the order. Transportation planning and execution are used when order and/or delivery documents are transferred into document exclusively. This is called freight unit document. The freight unit is measured to be smallest plannable object and unit represents example a pallet or a container. In Figure 20 example of freight units created from order or delivery document, and the input is for the transportation planning process. Based on the freight unit configuration, whether the freight unit is created based on the order or based on the delivery. Freight unit handling has functionality for splitting the quantities, especially in bulk material transportation. This splitting freight unit functionality is helping the planning, when you have possibility to prepare the received data from the order or delivery document.

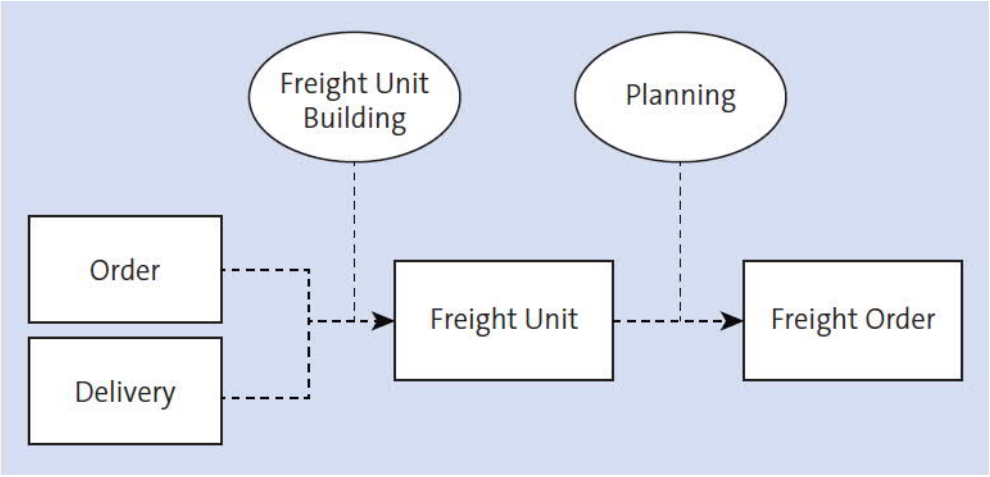

Figure 20. Document flow for transportation management. (Sauer. S, 2018)

5.1.6 Manufacturing with PEO

Flexibility in the Industry 4.0 is that the operation planning has achievable access to most current data from business functions. This requires simplified data model which allows access to a real time data ad updates upstream result. (Deloitte, 2017). In Figure 21 is presented the data exchange model.

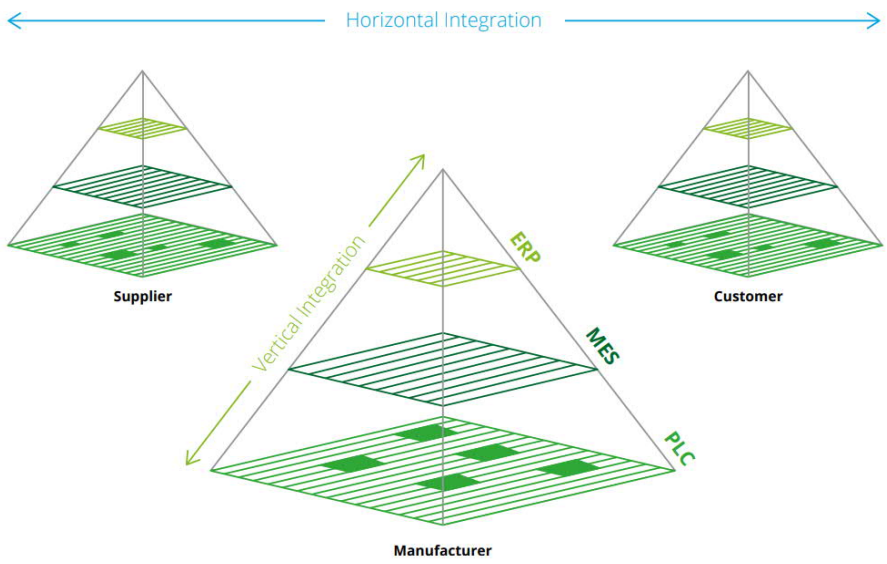

Figure 21. Data exchange. (Deloitte, 2017)

Manufacturing world has several challenges to cover with system perspective, short lead time with customer, increasing complexity with requirements, rapidly changing technologies and growing of regulations. SAP S/4HANA gives possibility for better plan, manage and monitor production. In Figure 22 is presented how the ERP has a new role in industry 4.0. Performance improvements are done for MRP programs, to see near real time data and react in short term accordingly. These performance improvements give possibility to planning organization to analyse the what – if analysis. (Deloitte, 2017)

Figure 22. New role of ERP in Industry 4.0. (Deloitte, 2017)

Production engineering and operations (PEO) is a positioning to provide operational excellence by eliminating the solos of MES/MOM solutions. Complex manufacturing target is to functionalities for extended supply chain with real time insight into WIP status, financial, supply chain, logistics and change impact analysis and there is no need for costly and complex integration between MES and ERP system, because the S/4HANA manufacturing is built on the S/4HANA digital core. PEO provides in manufacturing features to the production process in detail level, detailed instructions for production operators, follow that the production process is executed properly, and gives possibility to record production process data. Production engineering and operations are focusing to complex assembly process, where is possibilities to create and change manufacturing master data is based on engineering BOM and visualize both production planning and execution. When the S/4HANA is in digital core all the impact analysis has insight into all objects that can be affected when change includes orders, routings, BOM, inventory and inbound purchase orders which may need rework.

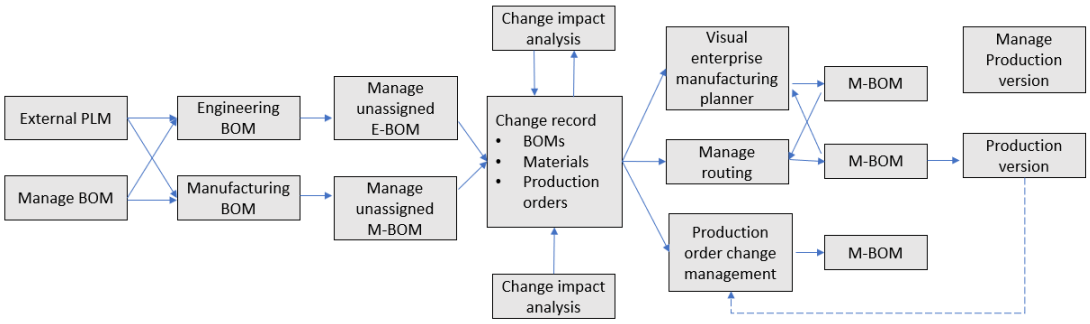

Figure 23. Design and manufacturing collaboration.

SAP tool for the design and manufacturing collaboration is targeted to have seamless environment from the design phases throughout the lifecycle of innovation, manufacturing, change management, service and support. As in Figure 23 is presented SAP PEO has been built so that it receives the design structure and handover consist of the model- based definition and EBOM and have optional for MBOM. Also, the PEO excels at intelligent change management. Change impact analysis in PEO has insight into all elements that may be affected by change incorporation. Insights have been built example into bill of material, routings, production orders, work in process, inventory, outstanding purchase orders. Change impact analysis is extendable to include also other objects. (source from company confidential material)

PEO production engineering between the manufacturing and design engineering providing seamless process flow and detail process plan definition. The handover has covered with 3D model-based visualization, quantity based nonvisual handover and hybrid scenarios. Here is listed possibilities/capabilities with PEO engineering to manufacturing handover:

- Model/unit effectivity
- Controlled BOMs and routings, and comparison of routing revision changes. Define the shop floor routings and improve routing maintenance.
- Change impact analysis identifies and highlights all objects that are directly impacted by the change guiding the user to the critical points
- Provides the operation activity granularity

- Rich text work instruction
- Define the inspection characteristics and have a flexible inspection
- Qualification and certification requirement specified
- Define the MBOM and routings with model unit
- Revision management for BOM and routing
- BOM net-change impact analysis
- Extended 3D support for manufacturing engineering process. 3D support eliminates the dual authoring and maintenance of 3D views and graphic attachments
- Add links to highlight components in 3D visual to assist in assembly.

5.2 Data Collection

Data collection for this case study was restricted to consist: production planning, warehousing and manufacturing (Figure 24). This chapter presents the data collection results from the in-depth meetings and comparing the capabilities described in chapter 5.1.

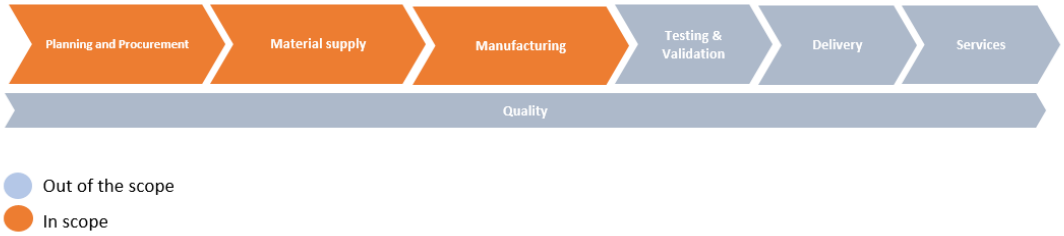

Figure 24. Data collection scope in process point of view.

The investigation and data collection had the focus on the future capabilities and practical benefits which would support the decision making in future. The data collection chapter is trying to cover the answer for the research questions as mentioned in the beginning:

RQ 1: What future capabilities of SAP S/4HANA could support manufacturing material flow / logistics in case company?

RQ 2: How the supporting supply chain solutions of the extended functionalities in SAP S/4HANA is giving benefits for case company?

The objectives for the theoretical part are to create knowledge about the Supply chain 4.0, SAP S/4HANA and the benefits of the system and describe future possibilities. The objective for the empirical part is to understand more in details the functionalities for supply chain and what are benefits for implementation.

The research meetings were planned and executed to be on each process segment and support function, so that the research will be focusing to the end-to-end perspective. Changing market trends forces companies to focus on the supply chain and start to transform to demand driven approach. Customer behaviour demands short delivery times, quick response time from need to delivery and that cause challenges to supply chain.

Collaboration and network with suppliers and partners require from the system perspective flexibility from integration point of view, functionalities and usability. Nowadays the challenge is error sensitiveness when lot of data is created and handled through the process.

5.2.1 Production planning

Integrated planning in case company is recognised as important planning method and considered as a focus area. The process consists of sales, R&D, supply and factory/capacity planning. These areas can be divided to SAP product categories as (Figure 25):

- SAP S/4HANA
- SAP IBP
- SAP Ariba
- Supply network planning
- SAP Cloud platform / Leonardo

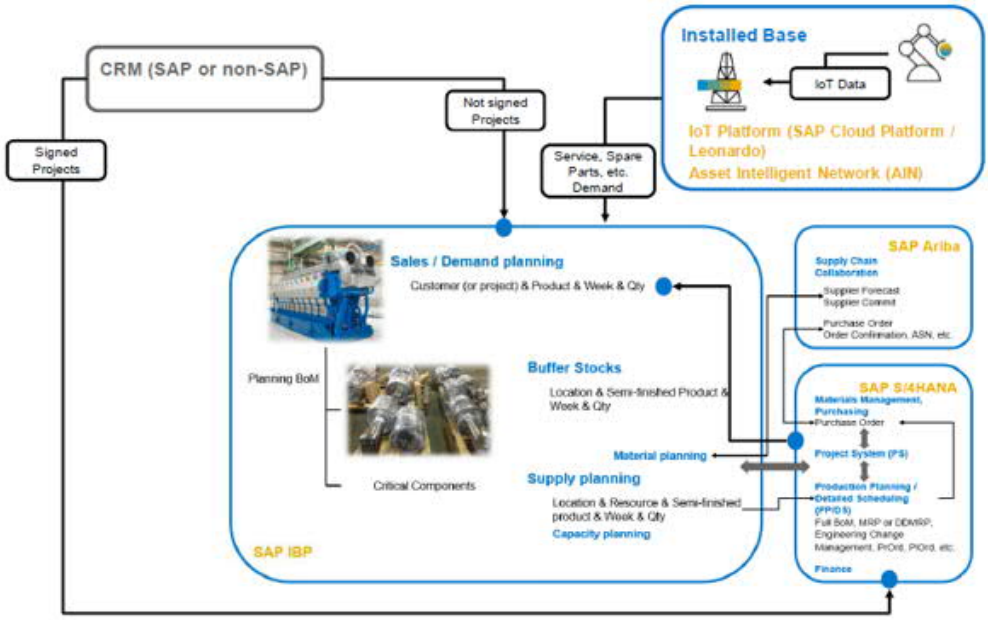

Figure 25. SAP planning summary. (SAP material, presented for case company)

Case company has part of the SAP S/4HANA capabilities covered with existing set up in SAP ECC 6.0. Nowadays the master production scheduling is in use from SAP production planning module. From the master production schedule, the data is visualized with a customized transaction for production plan. Production plan is done for delivery and production order level. On the shop floor/ work center level uses the production planning data for fine scheduling their own work center. This is causing issues for the reason that the fine scheduling is done in excel and the data is not transferred to SAP, so the data is old when it is taken from SAP. In the case company dependency in production is long and to have finished products for delivery the lead time is weeks/months. This means that when the master plan is not updated the material requirements are not correct and material deliveries are assumed based on the master production plan.

Other SAP modules/functionalities SAP IBP, Ariba and Leonardo/Cloud platform are not implemented in the case company but could bring value when considering the total supply chain.

Production planning framework can be divided into long range, medium range and short-range planning (Figure 26). Long-range planning is for longer horizon and from the case company's viewpoint it is greater than one-year horizon. Businesses together with market sales trend are determined Production planning is predetermining the varieties/constraints from the production, different quantities, quality and schedule of the products that to be proceed according to market.

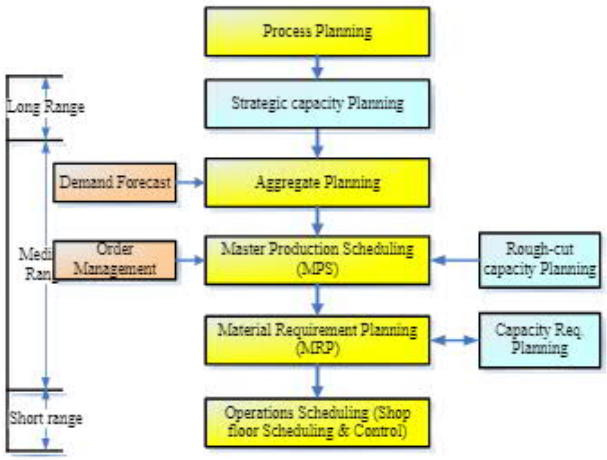

Figure 26. Framework of production planning activities. (Jiang. Z, 2017)

In case company the requirements for planning focus areas are to have better control for supply chain control tower, supply network, demand planning, inventory planning and operations planning. There can be seen that there are planning areas that are well defined and working, but integration between the areas needs to be in place to have a common plan. Production planning is the heart of the manufacturing operations. The challenges to success are the increased product complexity and customization, as well as the need of having the products quicker in the market for the customer. The fundament of efficient process and people management is the production planning. There are several issues what causes the pressure for production planning, and here those are listed based on the discussions:

- Technology is not supporting to manage planning, data is not visible and not updated. Optimizing own production plan the Microsoft excel is suitable, but to control constraints and relations between different production progress the information is lacking
- Visibility of the production progress based on real time data
- Production plan optimized without planning the possible downtime or disturbance
- The downtime caused due to the reacting maintenance instead of proacting asset management
- Factory capacity is not enough clear to secure the bottlenecks in process. Resource, asset or time buffer for capacity is not defined in enough detail level
- To solve the critical cases as a fire fighting, the continuous improvement in planning is not in good level

Detail scheduling in today's solution needs development in case company. SAP Detailed scheduling tool have key functionalities:

- Capacity-load optimization
- Optimal sequencing for production queue
- Graphical and flexible activity scheduling
- Manage the due date
- Backward and forward scheduling
- Simulation possibility and 'what if' analysis
- Plan monitor

- Possibility to configure exception alert monitoring
- Production order creation

Detailed production scheduling is the base of determining optimal production sequence for execution, understanding the actual constraints on the shop floor to commit on time deliveries. Here are listed some key benefits what the case company could reach by implementing the detail scheduling:

- Optimized production sequence that is feasible and can be executed
- Have a possibility to simulate various planning scenarios to determine optimal schedule
- Optimizing the schedule based on the actual constraints to ensuring reliable delivery due dates for customer
- Increasing throughput, reduces lead-time and improve the on-time delivery

Today's production and customer need forces to company to drive to proactive mode and have a transparency in supply chain. Take the advantage of the data what is available and build predictive analytics and blockchain. Try to build in the organization adaptability for agile and rapidly changing market.

5.2.2 Warehouse operations in case company

Today SAP Warehouse management (WM) is in use in case company. The SAP WM is large module in SAP and has not been implemented in full scope to case company. In Table **2** is presented the scope of the WM usage. Beside of the SAP WM, the case company has integrated all the warehouse tasks to manufacturing execution system (MES). Warehouse operation from goods receiving, putaway, picking and warehousing are integrated to MES. The master data of the warehouse is in SAP WM, and the MES is executing the SAP orders. Different order type examples are: purchase order, putaway order, request order and transfer order. In below Figure 27 the internal process from engineering to manufacturing is visualized.

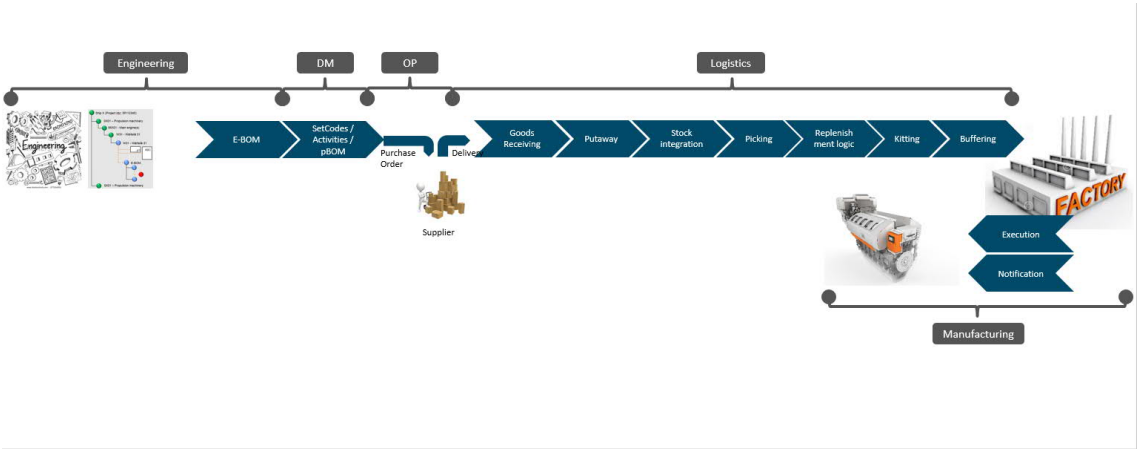

Figure 27. Case company the internal process

The SAP WM is in use with the scope defined in Table 2.

Table 2. WE SAP WM in case company manufacturing unit

Functionality / Plant	Case company
Transfer orders in 2018	180 417
Manage Stock at Storage Location	x
Warehouse Bin Management	x
Placement Strategies	x
Removal Strategies	x
Pick Logic	
Replenishment	
Standard Mobile RF Technology	x
Storage Unit Management	x
Handling Unit Management	
Yard Management	

Future capabilities from S/4HANA and extended warehouse management were mapped by interviewing the case company's logistics experts. Target was to find out the current solution related challenges and to understand the future requirements and needs. Process were divided into: inbound process, internal process and outbound process. Inbound logistics process includes goods receiving, unloading goods and placement in the warehouse. Internal logistics process is the handling the goods in the warehouse. Outbound logistics process is for storing, transporting and distributing goods to customer. Outbound process starts with sales order, continues with warehouse packing and ends

with product delivery. In the case factory the inbound and internal process are the main processes, and future requirements where defined for those. Outbound process was defined in the early state to be excluded from the scope, because it is so standard way of working. The processes inbound and internal where divided further to: core processes, cross processes and supporting processes.

Process analysis was done in a way that all the participants analysed the listed future capabilities beforehand, so that in the workshop all participants had understanding and opinion what is the reason for selected capabilities. Some of the listed functionalities were already in use in the case company, but the target was also to challenge current way of working. Processes marked was marked with “X” to describe in which category the functionality belongs. Categories where firstly defined with logistics experts to be:

- Needed, is already implemented in current solution
- Needed, but needs new process/implementation
- Nice to have
- Not needed
- Maybe

The idea of categorizing the need, was to have overall picture for options which should be consider as mandatory option or needs more clarification and understanding from process point of view.

One standard process in SAP EWM is a goods receipt when unloading the transport unit / the truck. Functionality is posting stock and is available in the EWM and can be moved with warehouse tasks. SAP EWM provides also to quality inspection further options to control goods receipt. The summary of the discussions is presented in coming figures and explained in detail the functionalities which are needed but there is not process or functionality in current system available:

Table 3. Inbound process, core processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Core process	Management of freight units		x			
	Goods receipt from delivery (expected GR)					X
	Deconsolidation					X
	Storage location management	X				
	Putaway	x				
	Returns Managament			X		
	Quality Assurance	x				
	Production receipt	x				

In Table 3 can be seen that there is new functionality ‘Management of freight units’ for case company, which can be seen as beneficial to implement. Freight units/order you can define the freight order types for transportation management. To improve the mixed pallet formation, freight units can be split and distributed on different pallets. This optimizes pallet formation and improves the truck utilization, which reduces transportation costs and lowers CO2 emissions.

Table 4. Inbound process, supporting processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Supporting processes	Warehouse management monitor			X		
	Warehouse cockpit			X		
	Performance dashboard			x		
	Dock Appointment scheduling					X
	Packing specifications					X
	Cartonizations					X
	Batch Management		x			
	Serial number management	X				

In the Table 4 there is a needed functionality batch management which is not implemented in case company. The batch management is to capture relevant details about the product that are unique. A Batch has a characteristic of the product and the characteristic has an impact how the product will be handled in the warehouse. To identify the product the batch management can be used.

Table 5. Inbound process, cross processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Cross processes	Yard Management			X		
	Task and resource management		X			
	Value added service		X			
	Dynamic cycle counting			x		

In the Table 5 there is a need for new functionality/process for task and resource management, and value-added service. Task management is like a transfer order item in WM. There can be two types of warehouse tasks: product tasks for product movements and handling unit task for moving handling units. Resource management is including workers and equipment performing warehouse tasks. Resource management supports to have effective utilization, manage resources, minimize the amount of deadheading in the warehouse, and helping to overcome capacity constraints. Value added service are services that are done on the products they receive into or there is faces issue in warehouse. Value added services can be for example kitting, labelling and packing.

Table 6. Internal process, core processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Core process	Handling unit management	X				
	Relocation and transfer	X				
	Physical inventory	X				
	Replenishment	X				
	Posting changes	X				
	Freight order management			X		
	Scrapping	x				
	Kit-to-stock		X			
	Kit-to-order (Vas order)		x			

In the Table 6 can be seen that there is a need for kit-to-stock and kit-to-order functionalities. Kit-to-stock process is where the kits are prepared based on the forecasted needs so that they can be available at the time of order is needed. Kit-to-order process is

reference to a customer sales order. This process is for kits which are not stocked in the warehouse.

Table 7. Internal process, cross processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Cross processes	Labor management		X			
	Task and resource management		X			
	Value added service		X			
	Dynamic cycle counting			x		

In the Table 7 can be seen that in cross processes new functionalities needed is: labor management, task and resource management and value-added service. Labor management is one of the elements in the warehouse to understand the employee workforce.

Table 8. Internal process, supporting processes

		Needed, is already implemented in current solution	Needed, but needs new process/implementation	Nice to have	Not needed	Maybe
Supporting process	Weight scale integration		X			
	Multiple EANs per product UoM				X	
	Material flow system integration		X			
	Radio Frequency enablement				x	X
	eSOA enablement					X
	Data import/export integration					X
	EH&S integration					x
	Transport integration LE-Tra		X			
	Multi client warehousing		X			
	Standard voice picking					x

In the Table 8 can be seen the supporting processes, where are listed out the needed functionalities: weight scale integration, material flow system integration, transport integration and multi-client warehousing. Weight scale integration is for when shipping and processing handling units weigh and post value to SAP. Material flow system integration gives possibility connect to automated warehouse solution. Transport integration gives possibility to have view for the transportation and more transparency on the process. Multi-client warehouse management is designed for the large distribution centres with complex and highly automated processes.

SAP EWM gives the warehouse process flexibility, performance and coverage. EWM is presented to give comprehensive warehouse management processes with full process transparency. It has a capability to flexible automated processes and supports medium and large-sized warehouses.

5.2.3 Manufacturing process

In the case company the manufacturing process is mainly the engine to order (ETO) process. It means that lot of customization is done through the process, and process needs to have agile way to handle the changes. Focus is nowadays to develop manufacturing process from R&D to manufacturing and then to services, to have an understanding how the product/service is built through the lifecycle.

Nowadays the challenges in case company are mainly in the change management process. There is several system operating to handle the change from source to end system and it is not seamless. Product lifecycle management and product data management (PLM/PDM) is level where the product related data is maintained and where the product lifecycle is managed. Target for the product data management is to ensure that all stakeholders share the common understanding and data, to minimize the confusion during the execution of the processes. In the case company the PLM/PDM data is structured from E-BOM to M-BOM before bringing the data to ERP system. Building and maintaining the M-BOM data is nowadays done partly in PLM/PDM side but also in Microsoft excel.

Operating in manufacturing level is important to understand the levels and responsibilities of different core solutions and system. The ISA-95 standard has been developed to understand the cost, risk and errors when implementing interfaces between enterprise and production control system (Figure 28). (Nearsoft, 2013)

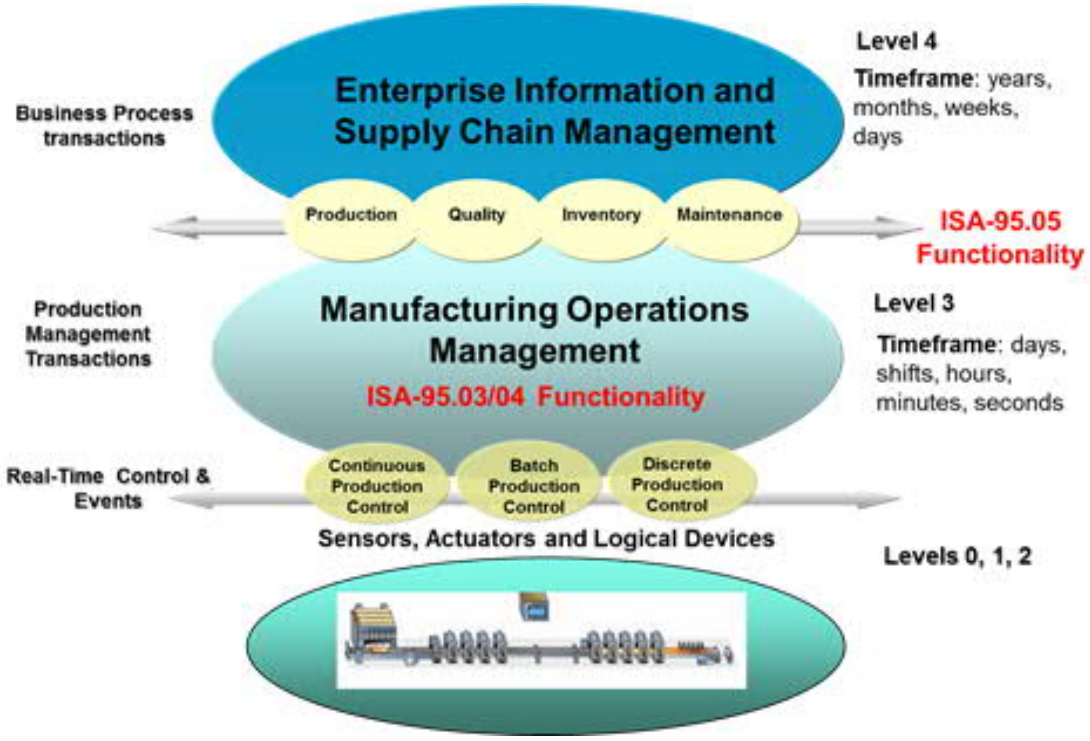

Figure 28. The ISA-95 standards of different operating levels. (Nearsoft, 2013)

The correct systems need to be operating and orchestrating in correct operating levels, and the responsibilities needs to be clear. There are nowadays needs as an example to have visualized the production progress and have all necessary correct data available, but what is the source system to use the data. When there is coming a change, how to have an impact from beginning of the process to whole supply chain and finally seen the change in production. The engineering change management is the topic is one big concern in the case company. How to handle the engineering change notice when there is a safety issue, customer change request, or example quality related issue. When the production is already ongoing and then comes a need for change, handling the changes in system requires lot of manual work and the risk is that the data is not correct. Compared to nowadays way working and the need is that related bill of material: drawing, 3D models, material list, documents, quality plan needs to be updated even the production is already ongoing. The system and process need to be supporting rework process, when there is engineering change.

In the working station there should be a transparent queue of orders displayed in the execution system. Rescheduling of orders could be possible, but then should have clear rules maintained for what kind of rescheduling can avoid the bullwhip effect.

The target is that all materials/components are divided into work-packages as apart R&D and manufacturing process. Each work package is assigned to a working sequence in the production order. Work packages are the guidance for the operator to manufacture the product in correct sequence and with correct work instructions. In the execution system it is possible the for-user drill-down work packages to see which components and activities are in the work packages.

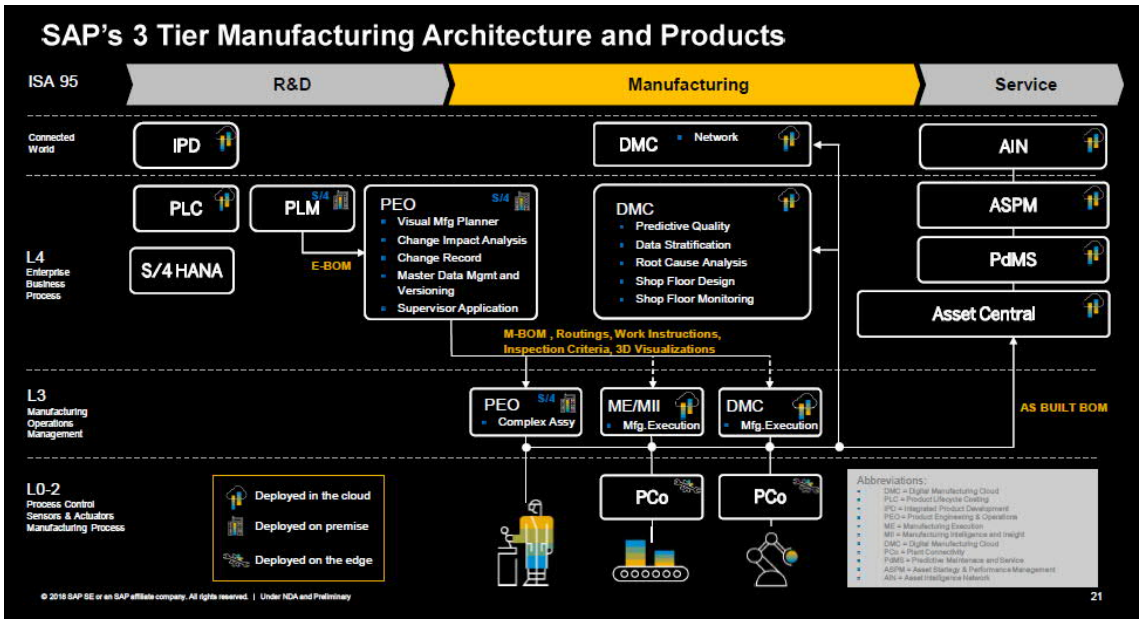

Figure 29. SAP S/4HANA Manufacturing architecture and products. (SAP company material, presented for case company)

Figure 29 presents the manufacturing architecture and products what is in S/4HANA. Production engineering and operations (PEO) tool is operating based on the ISA-95 standard level 4 and level 3. In level 4 the focus is on enterprise business processes and to maintaining the bill of material related topics. There is listed focus areas:

- Visual mfg planner
- Change impact analysis
- Change record

- Master data management and visioning
- Supervisor application

From PEO in level 4 system would give possibility to create the M-BOM, routings with a detailed flow of activities and allocated materials, work instruction liked to BOM, inspection criteria and 3D visualizations. PEO on the shop floor level support to execute the created plan and the structure (Figure 30). End user interfaces provides all relevant information ensuring that the correct activity is performed and completed using correct data. Tracing parts and part specific genealogy in shop floor when required.

Figure 30. SAP S/4HANA manufacturing for production engineering and operations. (SAP company material, presented for case company)

Compared to nowadays challenges the PEO could bring lot of new features and processes what are missing and are causing issues. One of biggest challenges is the engineering change management. To have a system supporting to change management and recording the changes, have possibility to impact on the shop floor. Handling the master data and

versioning has an impact on whole process. Usually the end user is the level where the data issues are seen. To have in place data driven manufacturing there needs to be supporting tools to maintain the data and correct it systematically. PEO has a capability to visualize the manufacturing planner support in creating and maintaining manufacturing processes and structure. Manufacturing processes and structures includes the manufacturing bill of material and routings by utilizing engineering structures (EBOM), and input through the visually guided planning process.

6 SUMMARY AND CONCLUSIONS

This thesis study describes how does SAP S/4HANA future look in case company and the investigation of the future tools and way of working. The thesis also investigates how the real-time optimized supply chain management could support to meet the variable manufacturing demand by creating smart supply chain that supports the demand driven supply chain. Thesis study consists of separate theoretical and empirical parts. The theoretical part in chapter 2 describes overall picture of the Supply chain, where selected main areas are Supply chain 4.0 and Industry 4.0. These both are describing the journey what the industry is going through and how the world is changing to more digital and proactive mode. The chapter 3 describes the SAP and SAP S/4HANA in high-level. The target is to have an overall picture of the new and coming features what could bring value to case company. The second part of the thesis is empirical findings, and it consist of defining SAP S/4HANA capabilities/modules for the supply chain. These selected modules were:

- Integrated business planning
- Production planning and detail scheduling
- Supply chain collaboration with Ariba
- Extended warehouse management
- Transportation management
- Manufacturing with PEO

Modules were described in chapter 5.1 in more details. Then in chapter 5.2 the case company processes were divided into three main categories: production planning, warehouse operations and manufacturing process. These three categories are aligning the features and capabilities described in 5.1 to current way of working and the challenges that case company is facing the nowadays processes.

The purpose of the thesis study was to investigate how the real-time optimized supply chain management could support to meet the variable manufacturing demand by creating smart supply chain that supports the demand driven supply chain. To get answer to these the thesis is divided into separate theoretical and empirical parts, by answering two research questions. For the first research question, *what future capabilities of SAP*

S/4HANA could support manufacturing material flow / logistics in case company? The findings show that the SAP S/4HANA core is well structured and there are lot of possibilities. The business needs to be understood and after that compare to the functionalities. Integrated business planning was seen to be a topic where at least case company should continue the investigation further. Planning was seen that needs more focus, and find out tools which supports strategy level, tactical level and operational level. The planning with tools which is in sync with different level is needed. This has direct impact to supply chain, suppliers, subcontractors, when there is planning changes in late phases and it is not transparent. The planning can see that it is going more to control tower concept where is covered the total chain planning, beginning from: engineering planning, supplier planning, inventory planning, production planning and collaboration planning. There is a lot of dependencies and constraints between different level of planning. To understand the planning in more concrete level the case company should investigate more the planning and consider creating model company for simulate the different possibilities.

The second research question, *how the supporting supply chain solutions of the extended functionalities in SAP S/4HANA is giving benefits for case company?* Case company has a lot of good things in place to reach benefits for implementing new processes. SAP S/4HANA is providing many good new tools for optimizing the supply chain. Processes where the case company has the challenges and should be investigated in more details. The core functionalities need to be working and in place to get most of the benefits measured.

How to Increase manufacturing flexibility based on real demand? Planning was seen one of the most important topics to get manufacturing stabilized. How the planning process could be standardized to have control tower concept in place and to have a centralized planning where the different orders are maintained and prioritized. There is nowadays to much fine scheduling and tools to maintain the real time planning and no impact on the master schedule. To make the decision for company level to optimize the product lifecycle management as a design or sales driven. There is an impact what is the correct level to optimize the material flow. How to plan the product lifecycle, how to plan for the material which demand decreases or product included into old product portfolio.

In the case company the PDM is Siemens Teamcenter. What are the best practices to do the tight integration between production when using the SAP S/4HANA PEO and the PDM data is in Teamcenter? The Teamcenter and SAP PEO integration should be further investigated to understand the system responsibilities compared to process what is desired. Important is to understand how the design can be used for complex manufacturing. For the future investigation point of view the manufacturing execution the engineering change notice handling is the topic what should investigated further. The engineering change notice handling is topic where are many constraint and different processes connected. To understand where the information is needed and when to have tight integrated support very complex and disturbance sensitive process. PEO has those elements presented and there are capabilities to have information flow from the design to manufacturing execution. When you do the design for manufacturing process in PEO, you would get the capacity need for integrated planning. Based on bill of material could the capacity be calculated. In addition to this the production flow through for the production line can be defined and what should be done and in which sequence.

For future investigations and my proposal for case company is that, IT landscape should be clearer and in understandable level. Ownership together corporate IT landscape and link to business processes.

The chosen research and the most suitable method in this case study was embedded single-case design. The reason for selecting the embedded single-case design is that even the SAP S/4HANA is divided and affects to several business processes, the system itself is single case. The approach for the study is to research capabilities from SAP S/4HANA to the case company.

The limitation of this study is that the results are based on theoretical assumptions and adopted for the case company. To have a validity of this research and results, the case company should implement the SAP S/4HANA. After the implementation the case company should cross-check the target of the implementation and find out if the targets were fulfilled. This research gives the information that the lot of potentials in SAP S/4HANA but needs to be understood the interfaces between the SAP and the other system.

The managerial implications in this case study are described as a link between theory and empirical findings on S/4HANA implementation. The findings and the business value of the research cannot be directly converted to scientific value, because the data are based on the case company. But the findings in general level can be leveraged and considered in companies. The general scientific value of this thesis can be the theoretical entity, and how that can be connected to complex production environment as in the case company. The value of this case study is the overall description of benefits and development areas that the SAP S/4HANA covers.

Before the case company should start or decide the SAP S/4HANA implementation, the compatibility for further solutions is required. The study gives the general understanding of the solution.

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