Information Usage in Smart Material Flows
– An Evaluation of the Prerequisites of how to Become Smart in the Material Flow from a User Perspective within Assembly at an Industrial Manufacturing Company

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Abstract

IT is a well-integrated function within most companies and its importance grows bigger by the day. With new solutions and concepts being introduced continuously it is important to be aware of the ever-changing possibilities found within IT. One of these changes is the concept of Industrie 4.0 which poses as a revolutionary way to do business by connecting the real world with the virtual one to a greater extent than what is done today. Research has shown that there are many possible benefits of implementing Industrie 4.0 and also Smart Factory, such as improved inventory control and faster reaction time. Since these concepts are quite new, no real definition exists and the congruence between the academic and business world is not always at the same level, and therefore the first steps are not yet defined. Therefore, this study tried to reduce the gap between these two worlds by offering concrete recommendations of what needs to be done to be able to apply Industrie 4.0 in the real world at Scania CV AB and Scania IT.

Scania CV AB posed as a case company to find out where to start on the road to become smart. Currently there are many functions using the services of Scania IT, but exactly how the systems are used is not known by Scania IT. To be able to provide the necessary services for the various functions of Scania CV AB and start the road of becoming smart, Scania IT needs to know how the systems are used and what information that is currently missing. A formulated strategy of Scania, as a whole, is to be able to collect and analyse information in order to have a more Intuitive Presence and Predictable Future, two words meaning that more proactive work can be conducted and more autonomous decisions can be made. To be able to fulfil this vision, knowledge about the needed information must be acquired by Scania IT.

With focus on the information connected to the material flow before the material reaches the assembly lines found at Scania CV AB the purpose of this study was to identify and analyse information and actions needed in the material flow from a user perspective, to become Intuitive and Predictable as part of the concept Industrie 4.0.

A set of research objectives were formulated as a guide for the study. By first identifying, with the help of the first research objective, the information input and output for the functions at Scania CV AB connected to the material flow, with a base in the functions planning material, it was identified that at different production sites different standards of working exist, but also differences in the IT usage and system configurations was found. The second research objective focused on what information should be available for production and material planning according to a literature review and this was later compared with the findings at Scania, which composed the third research objective. As it turned out, Scania uses the correct set of basic information such as forecasting, production plan, and calculations of gross demand, along with information regarding costs, lead times, and inventory. However, how to use the information is not standardized and the users of the IT systems perceived the information as hard to find and difficult to interpret. The fourth research objective focused on the concept of Industrie 4.0 and Smart Factories by studying literature, an external company and the ideas that Scania CV AB have, to see what must be done before a Digital Factory can be created.

The recommendations for Scania IT were based on the result on the analyses and they can be summarized by the need of further standardization of information and information usage to be able to start the road of becoming Smart and take one step closer to the concepts of Smart Factory and Industrie 4.0.
Acknowledgement

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Anna Eldered                                    Josefin Eriksson
## Table of Contents

Abstract ....................................................................................................................... i
Acknowledgement........................................................................................................ iii
List of Figures ................................................................................................................ viii
List of Tables ................................................................................................................ ix
Abbreviations .............................................................................................................. x

1 Introduction .............................................................................................................. 1
    1.1 Theoretical Background .................................................................................. 1
    1.2 Company Background ................................................................................... 2
        1.2.1 Scania Production System and the Modular System ......................... 2
        1.2.2 Scania IT ......................................................................................... 3
    1.3 Problem Description ....................................................................................... 4
    1.4 Purpose and Research Objectives .................................................................. 5
    1.5 Report Structure ............................................................................................ 5
    1.6 Delimitations .................................................................................................. 6

2 Method and Methodology ........................................................................................ 9
    2.1 Methodology .................................................................................................. 9
    2.2 Data Collection Method ............................................................................... 10
        2.2.1 Interviews ...................................................................................... 10
        2.2.2 Observations ............................................................................... 10
        2.2.3 Literature Review ......................................................................... 11
        2.2.4 Benchmarking ............................................................................. 11
        2.2.5 Validity and Reliability .................................................................. 12
    2.3 Analysis and Result ...................................................................................... 12

3 Frame of Reference ................................................................................................ 15
    3.1 Planning within Manufacturing ..................................................................... 15
    3.2 Planning Information .................................................................................... 17
    3.3 Material Planning ......................................................................................... 23
        3.3.1 Reorder Point System .................................................................. 24
        3.3.2 Base Stock System ....................................................................... 25
        3.3.3 Cover-Time Reviewing .................................................................. 25
        3.3.4 Material Requirements Planning, MRP ...................................... 26
        3.3.5 Internal Supply Methods ............................................................... 27
    3.4 Production Systems ...................................................................................... 29
List of Figures

Figure 1 The Scania Production System-house (SPS Office, 2007) ................................................................. 2
Figure 2 The Scania Smart Factory ............................................................... 3
Figure 3 The Scania Data Lake and its basic flow of information ................................................................. 4
Figure 4 The "U" adapted for the study with the research objectives at the respective parts of the report, inspired by Lekvall, et al. (2001) .............................................................................................................. 6
Figure 5 A system view commonly used for benchmarking. The input and system usage are both affecting the process which in turn generates an output. (Inspired by Bogetoft, 2012) .................. 11
Figure 6 Thematic and Templates Analysis. The above arrow illustrating Thematic analysis when themes are identified as the data collection goes along and the bottom arrow illustrating Template Analysis with a scheme defined before the data collection starts. (Interpreted from Saunders, et al., 2012) .............................................................................................................. 13
Figure 7 The main outline and structure of the study starting off with a comparative study and finalizing in an analysis and result of a model suggestion .................................................................................. 14
Figure 8 Basic data categories and possible ways of combining the information gathered in each category (Jonsson & Mattsson, 2003). .............................................................................................................. 17
Figure 9 All divisions that use the information in the databases at a manufacturing company (Inspired by Jonsson & Mattsson, 2003). .............................................................................................................. 18
Figure 10 Useful information for working with Reorder Point System (Jonsson & Mattsson, 2003) ... 24
Figure 11 Useful information for working with Base Stock System (Jonsson & Mattsson, 2003) ...... 25
Figure 12 Useful information for working with Cover-Time Reviewing (Jonsson & Mattsson, 2003) .. 26
Figure 13 Useful information for working with MRP (Jonsson & Mattsson, 2003). ......................... 27
Figure 14 Degree of information from order intake to delivery for different types of production (Jonsson & Mattsson, 2003) .............................................................................................................. 28
Figure 15 The different systems and the corresponding level of control (Romanov, et al., 2016) ..... 29
Figure 16 The tools used to answer the different types of questions when using BI (Loshin, 2013) .. 31
Figure 17 The four cornerstones of Cyber-Physical Production Systems - the Physical World, Data Acquisition, the Cyber World and Feedback/Control (Thiede, et al., 2016). ................................. 33
Figure 18 Global Processes for Order to Delivery (upper arrow, adapted, Johansson, 2013) and the focus area of the study .............................................................................................................. 37
Figure 19 The CPP process for generating Gross Demand originating from Distributors through to the setting of a production plan. .............................................................................................................. 38
Figure 20 Main information input, output and systems used by the CPP. .................................................. 38
Figure 21 Main information input, output and systems used by Purchasing. ........................................ 40
Figure 22 Main information input, output and systems used by the PPs in Södertälje ......................... 43
Figure 23 Main information input, output and systems used by the MPs in Södertälje. ....................... 45
Figure 24 Main information input, output and systems used by Internal Logistics in Södertälje. ...... 47
Figure 25 Main information input, output and systems used by the PPs in Zwolle. ............................... 48
Figure 26 Main information input, output and systems used by the MPs in Zwolle. ............................. 50
Figure 27 Main information input, output and systems used by Internal Logistics in Zwolle. .......... 52
Figure 28 How order information travels through the systems and how it is spread 31 ....................... 53
Figure 29 Some of the systems available at Scania and how they are interconnected to each other (Rosengren, 2014) .............................................................................................................. 54
Figure 30 How the call-off day is calculated in MC with information from SIMAS and MA 19.............. 54
Figure 31 Information input for Batch Call-Off 20 ....................................................................................... 55
Figure 32 An Assembly Order to a PRU becoming a Sequence Call-Off ............................................. 56
Figure 33 A visualization of the different configurations in SIMAS and when material is deducted or moved to the workshop balance ................................................................. 57
Figure 34 The three main components of Digital Manufacturing according to Virtual 38 .................................. 61
Figure 35 Summary of the possible methods according to Reorder Point System, Base Stock System, Cover-Time Reviewing, and MRP. .......................................................................................... 64
Figure 36 The information identified as having a major importance for planning orders, both externally and internally............................................................................................................ 66
Figure 37 A matching of the input available at Scania with the identified information found in the literature review using the Batch and Sequence Call-Offs and the production plan......................... 68
Figure 38 A visualization of when a demand occurs in SIMAS due to the chosen configuration compared to the actual demand time on line, based on Figure 33 (page 57). .............................................................. 69
Figure 39 A matching of the input available at Scania with the identified information found in the literature. The configuration in SIMAS and the inventory in general was proved to be of importance. ................................................................................................................................. 70
Figure 40 A matching of the input available at Scania with the identified information found in the literature. The lead times for material and costs found in the material flow affect the total material flow in many aspect, therefore this is a general figure................................................................. 72
Figure 41 Matching of Thiede, et al. (2016), Virtual Manufacturing and a dissected Scania Smart Pyramid................................................................. 74
Figure 42 The flow of information regarding the material flow and how the information flows between the different functions at Scania................................................................................................. 77
Figure 43 A matching of the input available at Scania with the identified information found in the literature................................................................................................................................. 78
Figure 44 A roadmap towards becoming smart, summarizing some of the most important steps. .... 79
Figure 45 The recommendations placed on the concluded roadmap..................................................................... 81

List of Tables
Table 1 Different correlations draw between Planning Levels and Planning Types (Jonsson & Mattsson, 2003; Segerstedt, 2008) ................................................................................. 16
Table 2 Summary of the important information found in relation to the Wilson Formula, Silver & Meal, and Wagner & Whitin (Oskarsson, et al., 2013; Jonsson & Mattsson, 2003; Wagner & Whitin, 2004). ............................................................................................................... 65
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGDA</td>
<td>Adaptive Gross Demand Administration</td>
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<tr>
<td>BI</td>
<td>Business Intelligence</td>
</tr>
<tr>
<td>COP</td>
<td>Customer Order Point</td>
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<tr>
<td>CPP</td>
<td>Central Production Planning</td>
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<tr>
<td>DP</td>
<td>Decoupling Point</td>
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<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>FOFF</td>
<td>Flow Oriented Factory Feeding</td>
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<tr>
<td>FRAS</td>
<td>Follow-Up Report Administration System</td>
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<tr>
<td>IM</td>
<td>Industrial and Marine</td>
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<tr>
<td>IMJ</td>
<td>Information Management Journey</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>KD</td>
<td>Knock-Down Assembly</td>
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<tr>
<td>KPI</td>
<td>Key Performance Index</td>
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<tr>
<td>MA</td>
<td>Mona Assembly</td>
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<tr>
<td>MATRIS</td>
<td>MATerial Requisition Information System</td>
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<tr>
<td>MC</td>
<td>Material Control</td>
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<tr>
<td>MES</td>
<td>Manufacturing Execution System</td>
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<td>MHT</td>
<td>Material Handling Time</td>
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<tr>
<td>MM</td>
<td>Mona Material</td>
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<tr>
<td>MP</td>
<td>Material Planner</td>
</tr>
<tr>
<td>NCG</td>
<td>Next Cab Generation</td>
</tr>
<tr>
<td>P&amp;L</td>
<td>Production &amp; Logistics</td>
</tr>
<tr>
<td>PFEP</td>
<td>Plan for Every Part</td>
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<tr>
<td>PP</td>
<td>Production Planner</td>
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<tr>
<td>PPAP</td>
<td>Production Part Approval Process</td>
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<tr>
<td>PRAL</td>
<td>PRoduction ALlocation</td>
</tr>
<tr>
<td>PRU</td>
<td>Production Unit</td>
</tr>
<tr>
<td>S&amp;OP</td>
<td>Sales and Operations Planning</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SFA</td>
<td>Scania Flexible Workhours</td>
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<tr>
<td>SIMAS</td>
<td>Scania International Material Administration System</td>
</tr>
<tr>
<td>SOTig</td>
<td>Scania Outgoing Transport and Invoice handling</td>
</tr>
<tr>
<td>SPARTA</td>
<td>Scania Production - Adaptive oRder allocaTion and bAlancing</td>
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<tr>
<td>SPS</td>
<td>Scania Production System</td>
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<tr>
<td>SS</td>
<td>Safety Stock</td>
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<td>SSD</td>
<td>Safety Stock in Days</td>
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<td>SSQ</td>
<td>Safety Stock in Quantity</td>
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<tr>
<td>STAR</td>
<td>Sourcing, Tracking And Reporting</td>
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<tr>
<td>TLT</td>
<td>Transport Lead Time</td>
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<tr>
<td>WIP</td>
<td>Work in Progress</td>
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1 Introduction

This chapter aims to describe the underlying factors of the study leading up to the Purpose and Research Objectives. First the Theoretical Background behind the study is presented followed by a presentation of the case company and why the subject is relevant for them. This leads up to the Problem Description and then the Purpose along with the Report Structure.

1.1 Theoretical Background

The theoretical framework regarding how to make Industrie 4.0 possible is still in its infancy and how to achieve a digitalized industry is quite unclear. At this stage, there is not much knowledge of how to create bridges between data collection and the use of the data collected. (Wikner, Persson, & Rudberg, 2016) Industrie 4.0 is defined by the traditional manufacturing and production systems being affected by a digital transformation. The Cyber-Physical Productions Systems, which Industrie 4.0 is composed of, are the connections between the real world and the virtual world. (Deloitte AG, 2015)

The connection between equipment, such as tools and machines, allows for a higher degree of coordination, which in turn allows for further optimization of throughput times, capacity utilization, and also for better quality in development, production, marketing, and purchasing. Furthermore, Smart Factories and machines are able to share information about for example stock levels, problems, and changes in orders or demand levels. With more units being connected, a smart infrastructure will be built, creating a platform for smart mobility, logistics, and grids amongst other things. Allowing for a full integration of Industrie 4.0 is believed to increase global competitiveness by, for example, reacting, and perhaps even predicting changes before they happen. (Deloitte AG, 2015)

To be able to respond to these changes and with a market that is becoming more and more complex, dynamic, and competitive, the access of data has become more important than ever. As a result, more data is collected in data warehouses to be used for Business Intelligence (BI) which in turn is used for reports and analytics to base decisions on. (Foshay, Taylor, & Mukherjee, 2014)

Even though there are some clear advantages of using BI, it is not used extensively by many companies. In order for BI to be fully effective it has to be developed in accordance with the strategy of the company and their priorities, but at the same time be scalable, flexible, and adapted towards its end-user. (Foshay, et al., 2014)

Understandably, the correlation between industrial digitalization and business value is strong today. The use of Computer Integrated Manufacturing and Industrie 4.0 emphasizes that industrial digitalization is possible with the usage of Internet of Things (IoT), Big Data analytics, and autonomous systems. (Wikner, et al., 2016) The IoT used within industry is called the Industrial IoT and this will enable industries to link manufacturing information to external intelligence, become more flexible in their manufacturing, and reveal information about the manufacturing processes that are yet unknown (Ehret & Wirtz, 2017).
1.2 Company Background

Scania CV AB (Scania) was established in 1891 and has since then become a global actor within heavy trucks, buses, and engines used for marine and industrial purposes. As a complement to the products Scania offers a diverse set of services ranging from services of heavy trucks to financial solutions for their customers. Scania recently became part of Volkswagen Group and will thereby start to cooperate with more MAN Truck and Bus (MAN) in the production and development of heavy trucks and buses as well as other companies within Volkswagen Group. (Scania CV AB, 2017a)

Scania products can be found all around the world, but the Production Units (PRUs) are located in Sweden, Netherlands, Brazil, Argentina, Poland, and France. As a compliment to the PRUs there are also regional production centres located in South Africa, Russia, India, Saudi Arabia, South Korea, Malaysia, and China. (Scania CV AB, 2017b)

1.2.1 Scania Production System and the Modular System

The foundation of all processes at Scania is the Scania Production System (SPS) which can be visualized and summarized with the SPS-house shown in Figure 1 below. The base of the house represents the three core values of Scania, namely Customer First, Respect for the Individual, and Elimination of Waste. The rest of the house and SPS consists of Principles and Methods, all done with the presence of Leadership. The principles, represented by the yellow blocks in the house, helps Scania in setting standards and generating reliable processes. The principles further emphasize the core values at the base of the house by only producing according to the customer needs which in turn supports the planning and reduces waste. By working with connected flows it is possible to receive information from nearby processes which helps levelling and balancing the flow at every process. The Priorities are found in green in the centre of the house, and their main function is to help with decision making. By primarily focusing on safety, health, and environment, but also complementing with the other levels of priorities, a base for how work is conducted at Scania is created. The connection of values, principles, and methods establishes a foundation for how to continuously improve and achieve results. (SPS Office, 2007)

![Figure 1 The Scania Production System-house (SPS Office, 2007).](image)

Scania uses a modular system to build all products and this is considered one of the major success factors of Scania. The modular system helps Scania achieve economies of scale and also to specify each product to the customer’s demands. The system further allows for new development within each
module to reach the market quickly by using standardized interfaces, since the standardisation of interfaces allows the main component to be developed while still matching the surrounding components. All in all, the modular system allows Scania to decrease the amount of parts needed while still offering a large set of variants of the product portfolio. (Scania CV AB, 2017c) The modules are divided up into five main categories; cabs, axles, frames, gearboxes, and engines (Scania CV AB, 2017d).

1.2.2 Scania IT

The first computer at Scania was bought in 1960 and since then the usage of computers and IT has increased. In 1986 the IT department was established which over the years has had different forms, but since 2012 the organisation is named Scania IT and is a wholly owned subsidiary of Scania. The assignment of Scania IT is to provide all units of Scania with the necessary software they need to have the processes run smoothly. (Oldenkamp, 2015)

One of the goals of Scania is to become a Smart Factory and part of Industrie 4.0. As a step towards this Scania IT has, together with Production & Logistics (P&L), developed what is called Scania Smart Factory. This pyramid has been inspired by Maslow’s Hierarchy of Needs where the lower levels need to be fulfilled first to achieve the higher level. At the bottom of the pyramid the focus is on having standardized processes which includes everything from the terminology to how the work is performed and also how the process is done itself. From this the higher levels are achievable, since, for example, the terminology needs to be the same when looking for patterns in the data. The top level of the pyramid consists of Intuitive Presence and a Predictable Future. These two mean that one should be able to know what is going to happen and act from there to avoid complications. The whole pyramid can be seen in Figure 2.

![Intuitive Presence, Predictable Future, Data Analysis, Data Gathering, Connected Technology, Flexible Standardized Processes](image)

*Figure 2 The Scania Smart Factory.*

In parts of the organisation multiple steps of the Scania Smart Factory has been implemented. However, the focus has mainly been on the finished products, and the patterns which can be seen when customers use it. This has been done using a data lake, called Scania Data Lake, that has been implemented by Scania IT and data has started to be collected. The goal of Scania Data Lake is to have all data accessible for everyone and thereby be able to create value for Scania and its customers by finding new insights based on the data. The data within the lake is supposed to be unprocessed to find correlations that are not affected by the way the data is structured (Scania CV AB, 2016).

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1 Project Engineer, personal communication, 2017-02-22
2 Lead Architect Order to Delivery, personal communication, 2017-03-28
3 Concept Developer, personal communication, 2017-02-15
The structure of the Scania Data Lake is that data is collected from various sources, such as the machines used by the production and information regarding orders, which is then processed in a Common Data Warehouse. Once the information is withdrawn from the lake a Common Information Model is used to create a structure to the information in a Business Data Layer, which then is processed in an Access Data Layer and/or a Performance Data Layer. The final aim is to produce reports that are useful in the production itself, as can be seen in Figure 3 below.

![Diagram of Scania Data Lake and its basic flow of information]

Figure 3 The Scania Data Lake and its basic flow of information.

Even though data has been started to be collected to Scania Data Lake it is not yet organized in a standardized way. At Scania IT people are working on finding a common way to structure all data and information at Scania, however a set standard is yet to be developed.

1.3 Problem Description

The information and generation of information from the material flow at Scania is affected by many functions, but also affects many functions. Some of the functions, such as Purchasing and Material Planners (MPs), have an direct impact on the planning in regards to the material flow, but there are many other functions that will continuously work with it such as Internal Logistics and Production Planners (PPs) planning the assembly lines.

The role of a MP is described by Scania as the person being “responsible for the procurement, delivery and management of the materials required for a business activity”. This indicates a need of information, by the MPs, from various sources, for acquiring material at the right time and in the right quantity. However, the way an MP works may differ between different PRU’s, indicating that there currently is a lack in the standardization of processes.

By studying the planning processes and the collected information and processed in connection to these processes, patterns connected to other functions such as Central Production Planning (CPP) order handling and Purchasing, are believed to be found. Much of the technology used in material planning...

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4 Scania Lexicon: [http://scania-lexicon.scania.se/termweb/app](http://scania-lexicon.scania.se/termweb/app), search term Materials Planner, 23 February 2017
is assumed to be connected and the data gathering has been started in some places. In fact, much data is believed to exist but not being used—indicating that there may be further analysis and correlations to be made to aid the MPs and the whole material flow. Yet, the systems implemented today are used as a tool to store information that is retrieved to produce reports manually, rather than allowing the system to execute the needed analysis and reports automatically. For Scania IT to be able to provide the necessary output it is needed to know what information is relevant to their users and what the information is used for.

Having an intelligent manufacturing system is a goal of Scania and Scania IT, and the base of an intelligent manufacturing system can be summarized by the Scania Smart Pyramid as seen in Figure 2. The base of the pyramid consists of standardized processes. However, the possibility of each PRU and MP not sharing data and calculations, impedes the flexible standardized processes. For Scania to progress towards their goal of having an Intuitive Presence and a Predictable Future a study of the standardized processes is needed in regards to information usage in the systems used and also in the daily tasks of the users of the systems.

1.4 Purpose and Research Objectives

The purpose of this study is to identify and analyse information and actions needed from the production support system, and its users, with regards to the material flow to become Intuitive and Predictable as part of the concept of Industrie 4.0.

As part of fulfilling the purpose five research objectives (ROs) were defined. During the study, they were used as a step by step guide to collect all the needed data and conduct the right analysis and fulfil the purpose of this study.

- **RO1.** Identify the information input and output connected to the material flow with a focus on the material planning process at different Scania locations
- **RO2.** Identify the information affecting the material flow according to literature
- **RO3.** Compare and analyse the information used at Scania and the information recommended by literature
- **RO4.** Compare and analyse what information is needed in a smart material flow at Scania by applying literature and available services on the market
- **RO5.** Formulate recommendations for Scania IT of what actions are needed to have an Intuitive Presence and a Predictable Future in the material flows

1.5 Report Structure

The structure of the report is summarized in Figure 4 on the next page and was inspired by the “U” presented by Lekvall, Wahlbin, and Frankelius (2001). Following the structure of the “U” allows both the authors and the readers to follow the general train of thought throughout the project (Lekvall, et al., 2001). The 1.3 Problem Description and the 1.4 Purpose and Research Objectives both posed as the framework of the study and indicated how the study was performed, which is explained in the 1.6 Delimitations.

With the base in the three above mentioned parts, the 3 Frame of Reference was created to serve as a foundation for the analyses done at a later stage, primarily for the analyses regarding RO2, RO3, and RO4. However, before the analyses were conducted an empirical study was conducted, found in 4 Current State, that answered RO1. By combining the empirical data and the result from RO1 with the
result from the literature review and RO2, a base for answering RO3 was established. Another comparison was done in the analysis for RO4. Chapter 9 Discussion includes a revision of the study and the work done, and how generalizable the conclusions are. As a continuation of the discussion are the specific recommendations to the case company, 9 Recommendations to Scania. The recommendations formulated to the case company are based on the discussion of the conclusion and are presented at the end, due to the degree of discussion that are included in them.

![Figure 4 The "U" adapted for the study with the research objectives at the respective parts of the report, inspired by Lekvall, et al. (2001).](image)

### 1.6 Delimitations

The study has only considered the processes affecting the material flow at the different assembly lines at Scania’s production sites in Södertälje, Sweden, and Zwolle, the Netherlands, and a generalization was done thereafter.

Due to the limited amount of time for the study it was not possible to cover all aspects of the material flow and the information connected to it. As a result, the study has been done on a general level, meaning that no specific product was studied, but rather the functions handling the various products as a total flow. Moreover, due to the time limitations it was not possible to interview every interviewee more than once. The interviewees that were interviewed multiple times was mainly those who were experts in their field and no other source of information was identified. In general, the chosen functions to be interviewed are part of the central Order to Delivery process, which includes CPP, Purchasing, PP, MP, and Internal Logistics. Other functions, such as Quality, was not studied since an assumption was made that, in theory, there should not be that many deviations that affect the material flow.

How the information was collected, processed, and complied in a technical way was outside of the scope of the study, as was the implementation of the proposed recommendations. The time limit and the limited knowledge about how IT systems are developed and therefore not part of the purpose. Therefore, the information structure and the specific guidelines to create a flow logic was not considered, meaning that the information that was taken into consideration was only looked upon in terms of usage and if more information could add value, and not how for example Scania Data Lake should structure the gathered information.

Since Scania is a big company there are many projects going on at the same time and continuously being implemented. As a result, a decision was made to not consider all projects and to focus on three
projects that have a direct impact on the ROs presented for the study. The chosen projects include a centralization of the MPs, better understanding of the information found in the systems, and Scania Data Lake.
2 Method and Methodology

The method and methodology used in the study are described below together with arguments for choosing each technique. First the methodology and the standpoints are presented followed by a deeper presentation of how the study was conducted. Different aspects are brought up and compared to give the reader an understanding of why the method was chosen. At the end of the chapter the analysis and report structure is described in greater detail to put the purpose and ROs in their context.

2.1 Methodology

This study was based on two cases; the material flow from a planning perspective within assembly at Scania in Södertälje and in Zwolle. Case studies can include multiple cases and have different aims such as provide a description of a situation, generate theory, or test theory, by combining data collected in different ways. By conducting a case study the focus is to understand the dynamics of a specific environment or setting and get a deeper knowledge of it. (Eisenhardt, 1989). In this study the aim was to provide a description of the material flow in Södertälje and in Zwolle to create a deeper understanding but also to be able to compare and analyse the different cases.

The study was a qualitative study based on observations and interviews. These two ways of collecting information compose a good complement to each other according to Björklund and Paulsson (2013) and the investigation of the processes is also a representative of a qualitative study. In the study there are no quantitative parts since a map out of a process is hard to do in a quantitative way and it was considered better to explore all processes since no or minimal previous knowledge existed among the researchers about the material flow at the case company.

The study took on both a descriptive and a normative approach. Björklund and Paulsson (2013) defines the former as a good tool when basic knowledge exists and the study’s purpose is only to describe the case, not to investigate correlations, between the studied objects. This proved useful during the study’s first two research objectives where the aim was to investigate the current state of the planning process. The latter, the normative approach, is described by the same two authors as a study within a field where there already is sufficient information and the aim is to offer guidance and actions (Björklund & Paulsson, 2013). The normative approach was mainly used for the last two research objectives, and posed as the future state of the study where guidelines and suggestions were given.

Together with the descriptive and normative approach an inductive approach was primarily chosen. The inductive approach is based on the real world and its facts and then theory is applied to the study. As for the study, a natural starting point was to understand the problem which material flow and Scania face by studying the real world first hand. By then considering the information, available theories describing the correlations and analysis tools were investigated from literature and other sources, as described below in 2.2 Data Collection Method. To be able to use triangulation, as is explained further in 2.2.5 Validity and Reliability, the inductive approach was complemented with a deductive approach. The deductive approach can be described as starting with understanding the underlying theory, for example with a literature review, and afterwards the collected data is said to verify what was found. A combination of inductive and deductive approach is the abductive (Björklund & Paulsson, 2013) and as a result this study contains some major elements of an inductive approach and minor elements of deductive, making it an abductive study overall.
2.2 Data Collection Method
To find data to answer the purpose and research objectives different types of data collection methods were chosen which will be described in the following chapter.

2.2.1 Interviews
Data collection through interviews allows the collection of primary data and interviews can be sub-categorized into three different types of interviews; structured, semi-structured, and non-structured interviews. A structured interview has all of the questions pre-made and the same set of questions are asked to each and every interviewee. A semi-structured interview also has pre-defined questions, but allows for follow-up questions and discussions. A non-structured interview consists of a discussion where questions arise as the discussion progresses. (Björklund & Paulsson, 2013)

The non-structured interview is a good way to start a research project to get an understanding for the topic and the problem that will be studied. This is because the non-structured interview may lead to a wider perspective and more information being revealed. (Gillham, 2005) To receive more standardized answers that can be compared more easily, the structured interview is more suitable. This is due to the questions being asked in the same manner every time and the interviewer can give possible answers to choose from. (Bryman & Bell, 2003)

The weaknesses found in connection with conducting interviews are, for example, that they are time-consuming and follow-up questions might be necessary if the questions were not answered sufficiently. However, the benefits of conducting interviews consist of the interview itself being a primary source of information and additionally they allow information in direct connection to the study at a level that is adaptable, allowing for a greater understanding. (Björklund & Paulsson, 2013)

For this study semi-structured and unstructured interviews were held during the entire course of the project. During the first time period of the study, during the evaluation and search of the study’s purpose and research objectives, the interviews were unstructured to find possible research areas and to get an understanding. As the project progressed the interviews took a form of being more and more semi-structured, allowing for in-depth understanding and follow-up questions. As a rule, there were two interviewers present during every interview to allow a better understanding of the responses (Voss, Tskirktisis, & Frohlich, 2002). All interviews were also written down, to enable the researchers to go back and revisit the answers.

2.2.2 Observations
Observations can, just like interviews, be sub-categorized into various forms depending on the involvement of the observer. The two extremes include the observer doing the observation without any interaction and the other extreme is the complete involvement of the observer. Since observations may take various forms there are advantages and disadvantages found in connection with every observation itself. As a general rule, there is a risk of observations being time-consuming, but at the same time it may offer relevant and objective information in return. (Björklund & Paulsson, 2013)

The observations conducted as part of the study were study visits done at the assembly lines. The study visits were conducted to get a deeper understanding of the production system, as well as the planning procedure. Furthermore, some observations were done in combination with interviews where the interviewee was asked to show how the work was executed with the present information and also what other information that could have been useful. As in the case with interviews, a general rule of having two observers present during each observation was set.
2.2.3 Literature Review

Literature was reviewed to broaden the perspective of the study. A literature review is a good way of acquiring information and facts already established by others and different types of written sources can be used, for example articles, books, and reports. It is important to plan the literature search, to not let it drag out and before starting looking for literature, relevant areas can be established to organize the search. (Bell, 2000) For this study mainly articles and books found through search engines, such as Science Direct and Scopus, were considered, but also internal documents and information systems at Scania were taken into account. Examples of search words used was Material Flow, Material Planning, Production Planning, and Planning Information as well as Business Intelligence, Industrie 4.0, and Smart Factory.

Literature and literature studies are considered a secondary source of information. The risk of using secondary sources of information is that the material published very often has another purpose and the method used to find, analyse, and interpret the information is not always known. However, an advantage of using a literature study is that the researcher quickly will find relevant information in the creation of the frame of reference. (Björklund & Paulsson, 2013)

2.2.4 Benchmarking

Traditionally benchmarking means that managers compare their organization with documented best-in-class organizations. These comparisons can be done in regards to products and processes as well as the whole organization. Bogetoft (2012) identifies the first part of benchmarking as the selection of a product, service or process and at the same time identify what it is that should be compared. Following this step is the collection of data and conduction of an analysis of the data available in relations to what it is that is compared. (Bogetoft, 2012)

A common way to go about comparisons, and especially when using benchmarking, is to use a systems view. Bogetoft (2012) uses economic performance benchmarking and thereby refers to input as bad, closely related to costs and expenses, for the business and output as good in general terms, closely related to income. However, Bogetoft (2012) also points out that there may very well be other types of input that are not bad and input may take other forms if not compared with economic factors. Non-controllable factors that may affect the process should also be taken into consideration, such as the skill of the workers. (Bogetoft, 2012) For this study an adaptation was made and a system view as used to visualize the input, output, and the systems used as can be seen in Figure 5 below.

![Figure 5 A system view commonly used for benchmarking. The input and system usage are both affecting the process which in turn generates an output. (Inspired by Bogetoft, 2012)](image)

In this study a benchmarking approach was conducted primarily to compare Scania Södertälje and Scania Zwolle. The comparison was applied by studying the differences in working methods and information usage. Furthermore, the input from an external company was used to get an understanding of how suppliers of Smart Manufacturing systems are working. A fourth perspective
was brought in with the usage of a literature review to understand further and ensure a better reliance on the results of the study. The application of Figure 5 was used as part of mapping the information input and output connected to the material flow. Additionally, an external company was interviewed to allow the study to benchmark Scania’s mindset and progress, as well as tools, with an outside actor. The company was chosen due to its proximity to where the study took place and also wide knowledge within Smart Manufacturing. Additionally, the customers were in a similar business segment with both manufacturing and assembly, and the reputation of the company proved good.

2.2.5 Validity and Reliability
A useful tool when studying the validity, reliability, and objectivity of a study is triangulation. Björklund and Paulsson (2013) primarily use triangulation in regards to different methods and the object of the study as a way of increasing the validity of the study. Another way of increasing the validity of the study is to have a clear description of what is going to be studied, and who will be interviewed about what. (Björklund & Paulsson, 2013)

Reliability is the degree to which the results of the study are repeatable. The usage of control questions, where multiple interviewees are asked the same questions, can be done to ensure a higher degree of reliability. Objectivity, on the other hand, is to what degree personal values affect the result of the study. This is especially the case when working with interviews and to ensure a higher level of objectivity the decisions taken during the study have to be shown to the reader. Furthermore, it is important to be aware of the fact that information might be re-cited wrongly. To mitigate this risk, hard facts need to be compared to the collected information and all interview notes checked by, preferably, the interviewee. With that said, there should be no selection of fact, but rather all facts should be presented and not only the ones supporting the idea of the study. (Björklund & Paulsson, 2013)

Regarding the objectivity of the study, the positions which the authors take in relation to a positivistic and a non-positivistic view should be considered. The former state that there exists studies which are objective whereas the latter state that is it not possible for the authors to be 100% objective. With that stated there are great considerations to be made in regards to honesty, ethics, and morality. (Björklund & Paulsson, 2013)

The use of triangulation can primarily be seen in the usage of multiple interviews together with the conducted observations on one side and the literature study on the other. Furthermore, the interviews are not fully objective and will always be influenced by the interviewers in their questions and interpretations, as is the case with observations. However, measures have been taken when interviewing people, such as ensuring the questions are understandable and clearly formulated. Furthermore, complementing the interviews and observations was the literature review, with collected data from various authors, together with continuous supervision of the supervisors of the study.

2.3 Analysis and Result
What type of analysis method that is suitable for a study depends on characteristics of the collected data and how it is structured. The first thing that needs to be done is to code the collected data. This can be done according to a pre-defined schema, either composed by the researchers or a third party, or it can be defined iteratively as the data gets coded. (Saunders, Lewis, & Thornhill, 2012) When
analysing qualitative data there are no strict rules that has to be followed. The methods that exist are rather guides to help finding patterns and structuring the data. (Williamson, 2002)

There are different methods of doing the analysis and the data coding, and two defined methods are Template Analysis and Thematic Analysis. The Template Analysis first uses an inductive approach and then a deductive approach. The Thematic Analysis, on the other hand, starts off with a deductive followed by an inductive approach. (Saunders, et al., 2012)

Template and Thematic Analysis are done in similar ways. The main difference is that when coding the data following the Template Analysis method the coding schema is created as the data is collected and themes identified, and when using Thematic Analysis Method, the coding schema is defined beforehand and all data is coded before starting to search for themes within the data. How the coding is done according to the two methods is visualized in Figure 6 below. (Saunders, et al., 2012)

The theme search can be done over and over to find the most suitable themes, explanations, and patterns. Once the theme search is considered done the findings are refined. Some data might not fit into the found explanations and they are called negative cases. The negative cases should be viewed as something positive, since they lead to a deeper understanding of the problem. (Saunders, et al., 2012)

In this study both Template and Thematic Analysis were used and the process of the work can be seen in Figure 7 on the next page. The processes and information flows at each function at the two production sites were identified to get an overview of them to see differences clearly and make a comparison. First, the case in Södertälje was studied and the data was coded into systems views for each function as it was collected, since the area was not previously explored. The coding schema was defined as more data was collected, and some data was re-categorized once new information was collected. The case in Zwolle was studied afterwards and then the same coding schema and systems view was used as for Södertälje. This was done to be able to easily compare the information collected and used at the different sites and composed the main empirical collection of data.
The analyses were conducted in steps and based on each other. First, the findings in the literature review were analysed to identify what data that is most commonly needed in order to be able to plan the material flows. The main information needed to be known when planning according to the literature was then compared to the systems view and other information found for the functions involved in the material flows at Scania. This was done in order to identify if any information was missing, or if any information currently at Scania is unnecessary to have. Aspects affecting the information flow at Scania was highlighted as well, for the recommendations made to Scania IT to be as realistic as possible.

Once the comparison between the analysed literature review and Scania was done a third analysis was conducted which identified the concept of Smart Factories and Industrie 4.0 and how it can be achieved. This was done by comparing the studied literature and benchmarking with an external company which was then matched with Scania’s concept of the same theme.

All in all, the analyses generated the foundation for the recommendations to Scania IT of how Scania can become more smart, in the sense of using the concept of Industrie 4.0 to a greater extent. These recommendations work as a roadmap of how becoming smart is possible, since gaps in the information gathering and the foundation in becoming smart were partly missing.
3 Frame of Reference

This chapter primarily consists of material planning methods and methods for supplying the production with material. First planning is described and information that may be of use when planning is defined and presented along with different ways to material plan and batching material. Thereafter, IT-systems used within production is presented and described to give the reader a basic understanding for how they work and are connected. The chapter ends with Digitalized Manufacturing and how production may be developed and what tools that are available to become smart.

3.1 Planning within Manufacturing

Planning is often categorized into three different levels; Strategic, Tactical, and Operational Planning. Each level has its own characteristics and emphasis is put on different aspects. The Strategic Planning is long term planning, that usually lasts for more than a year regarding the overall goals of the company, together with the resources and capacity needed. The Tactical Planning aims to ensure the Strategic Plan is fulfilled, and the planning is more detailed than planning on the Strategic level and focuses on a shorter time period of six months up to a year. At this level the capacity is planned in greater detail and production plans are formulated. The lowest level of planning is considered to be Operational Planning which focuses on the day-to-day activities of the company, involving a great deal of administration to support the Tactical and Strategic levels. (Jonsson & Mattsson, 2003)

Segerstedt (2008) draws a parallel between the Strategic, Tactical and Operational planning by referring them to different planning types as can be seen in Table 1 on the next page. He regards the Master Plan as a plan on the Strategic level, Detailed Planning as tactical, and the daily work as operational. By making this statement it is easier to relate to the different planning levels within a company. (Segerstedt, 2008) Jonsson and Mattson (2003) supports this idea stating that all companies do not have the same division between levels and types. In fact, one common example of this is combining Sales and Operations Planning (S&OP) and the Master Plan into one type called the Master Plan. However, Jonsson and Mattson (2003) also defines the time periods for which the different planning types differently than Segerstedt (2008) does, also seen in Table 1 on the next page.

According to Jonsson and Mattsson (2003) the S&OP is connected to the long term of one year or longer, followed by the Master Plan of six months to one year, Order Planning up to six months and finally the Workshop planning which is done on a weekly period. Nevertheless, all authors agree upon the fact that at what detail the planning is done at, is what is most important, where the first types and levels of planning, done for the long term, contain less detailed information than the lower levels with a shorter time horizon. Furthermore, some types of planning can be cross-functional and be part of various levels. One example of this is Material Planning which is present in various levels, as seen in Table 1 on the next page. (Segerstedt, 2008; Jonsson & Mattsson, 2003)
Table 1 Different correlations draw between Planning Levels and Planning Types (Jonsson & Mattsson, 2003; Segerstedt, 2008)

<table>
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<td><strong>Strategic Planning</strong></td>
<td>S&amp;OP</td>
<td>Master Plan</td>
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<tr>
<td><strong>Tactical Planning</strong></td>
<td>Master Plan</td>
<td>Material Planning</td>
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<tr>
<td><strong>Operational Planning</strong></td>
<td>Order Planning</td>
<td>Detailed Plan</td>
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<td></td>
<td>Workshop Planning</td>
<td>Operative Work</td>
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S&OP aims to, for a long period of time and at a higher level, provide general plans regarding sales, deliveries, and production. The aims and goals of the company are represented and formulated on this level. (Jonsson & Mattsson, 2003) Supporting the S&OP is the Master Plan, which plans the deliveries and production plans in relation to the existing order stock. Today, much of the Master Plan is generated automatically and is rather similar to Material Planning, especially in the case of companies producing standardized products. However, there are some parameters that are important to this type of planning. Jonsson and Mattsson (2003) have developed their own general step-by-step method for the process of master planning, consisting of five steps:

1. Create a forecast of the future demand
2. Create a preliminary delivery schedule based on the forecast and the current customer orders
3. Create a preliminary production plan based on the preliminary delivery plan and the actual and the wanted inventory levels and order size
4. Check whether the created plans and the conditions are realisable, for example in regards to material and capacity. Adaptions should be made if needed
5. Set the production plan

Segerstedt (2008) works in a similar way and also bases his Master Plan on the order intake and the forecast to finish off the planning with the question whether the plan is realistic or not, if yes, then Capacity and Material Plans are created.

The next level of planning is made in more detail and considers the material which is needed at the company and this is the Material Planning (Segerstedt, 2008). Jonsson and Mattsson (2003) regards this as Order Planning, which involves Material Planning and deciding what quantity and when the quantity is needed. The aim of Material Planning is to provide a material flow which is efficient in regards to capital, delivery service, and resource utilization. In other words Material Planning focuses on the material, the quantity, the delivery, and the starting time. In the ideal case Material Planning would time the material flow perfectly with the demands in later stages. However, working with an ideal state is hard and company strategies have to be formulated as to how the inbound and outbound material should arrive and depart. (Jonsson & Mattsson, 2003) Segerstedt (2008) summarizes some of the tasks of an MP as securing the material supply through:

- Order material in relation to the production plan
- Make pre-orders if these are needed
- Reserve material if needed
- Create material plans including purchasing orders and home produced orders
- Ensure plans are followed
- Create material need calculations unless provided by the Master Plan
- Update changes in, for example, lead times and quantities
• Calculate and update order points
• Manage inventory levels

At the same level as Material Planning is the Detailed Planning and the Capacity Requirement Planning. The Capacity Planning focuses on creating a balance between availability and demand. By making this balance, it may be used on all levels of planning but it is mainly at the Detailed Planning level the plans are set. The last level of planning identified by Jonsson and Mattsson (2003) is the Workshop Planning, which includes the day-to-day work and follow-up of the plans made on the earlier planning levels. (Jonsson & Mattsson, 2003) The Detailed Plan, according to Segerstedt (2008), supposed to ensure that delivery times are met, the Master Plan is followed, the flow is even, all material, equipment, and tools are in the right place at the right time, and, finally, ensure that the costs for Work in Progress (WIP) and storage are kept at the desired level. The Detailed Plan is done for a shorter time period and in more detail than the Master Plan, at the same time sending back information about the production result to the Master Plan. (Segerstedt, 2008)

3.2 Planning Information

The base for making the right decisions within production and material planning is information and data. The data needed is mainly information about the products and the processes within in the company, and the so-called basic data can be categorized into four categories each communicating between themselves. The basic data categories are, as can be seen in Figure 8 below, Article, Structural, Operational, and Production Group Data. Each category collects different information and by combining information and also the different categories a compilation can be made. (Jonsson & Mattsson, 2003)

![Figure 8 Basic data categories and possible ways of combining the information gathered in each category (Jonsson & Mattsson, 2003).](image)

Article data concerns the specifics of the product, such as information regarding its weight, measurements, article number, and what ordering unit. Structural data, on the other hand, rather focuses on the product when it is produced. Examples of Structural data includes the composition of the product, what raw materials are being used, and the components needed in the production process. What resources that are needed in the process together with the information about the transformation processes at the company is categorized as Operational data. Production Group data includes information about the production resources and how much that is available. (Jonsson & Mattsson, 2003)

These four types of data are usually divided into four different databases which can be combined in different ways to give, for example, the planners the information they need. The collected information may be used by different divisions in a company and they all use the data in different ways. (Jonsson & Mattsson, 2003) The different divisions are shown in Figure 9 on the next page, which includes Customer Order Processing, Construction and Production Development, Production Technique,
Purchasing, Production Control, and Material Control. Each of these use the data bases for their everyday usage to function within their environment.

Information can also be categorized by studying the end-user. Mattsson (2012) then divides the information into four groups according to the information’s relation to the external parties of the companies. These four categories are Structural, Activity, Planning, and Follow-Up information. Structural information refers to the information which concerns stakeholders within Supply Chain Management. Supplier and customer information includes information such as addresses, contact personnel, agreements, and performance measures. In general, the Structural information is fixed, meaning it does not change very often and does not have much impact on costs and efficiency. (Mattsson, 2012)

The Activity information is information that can be related to values that change at relatively frequent intervals such as production plans and current production. Therefore, this type of information is the one needed to optimize the processes and the production. This also includes information regarding needed material and material flows. (Mattsson, 2012)

Planning Information consists of all information that creates the base for the planning process. This includes historic data as well as new data. However, the new information is usually delayed timewise through the steps and thereby forecasts will be needed as a complement to fill any gaps. (Mattsson, 2012)

The last category of information, according to Mattson (2012), is Follow-Up information. This information is not as time critical as the Planning information. This information regards the real outcome of processes but also opinions of the customers. (Mattsson, 2012)

Information can be exchanged on different levels within a supply chain and according to Kiil, Dreyer, and Hvolby (2015) four dimensions decides what level the information exchange is at. The levels are frequency and timeline, neighbourhood, information content, and information detail. These four levels together decide when and how often information is shared, with whom, how much, and in what detail. (Kiil, et al., 2015)

One aspect of information sharing is the willingness to do so. By being willing to share information with other parties of a supply chain the performance of the entire supply chain may be enhanced. However, the aspect of connectivity is also important for the information sharing to be efficient and relevant. By combining these two, benefits such as shorter order cycles and enhanced delivery performance may
be achieved. If one of the two is established some benefits can be identified. For example, if connectivity exist but not willingness, non-sensitive information may be shared. In the opposite direction, if willingness exist but not connectivity, the information may be shared but not as fast and efficient as it needs to. When both connectivity and willingness is there, a trusting relationship is established where information is shared frequently and unique collaborations can be found. (Fawcett, Osterhaus, Magnan, Brau, & McCarter, 2007)

An important aspect regarding information is the information quality. Information is considered to be both subjective and objective since it depends on the expectations of the information and whether or not it fulfils the requirements. This is important to have in mind since it affects how the quality of the information is measured. (Eppler, 2006) Grudzién and Hamrol (2016) point out that no standard for information quality has been established regarding management systems, but Mattsson (2012) has identified three aspects that can be used for accomplishing information quality, namely that it needs to be correct, time-relevant, and complete.

The correctness of the information regards both the validity of the information as well as the reliability of the information. The validity means that all parties that take part of the information needs to interpret it in the same way and the reliability of the information means that it comes from a trustworthy source. (Mattsson, 2012)

The time-relevance of the information means that it needs to be delivered at a time which makes it relevant to the receiver. If information arrives too late it will not be as relevant anymore, or perhaps even irrelevant. The completeness of information means that enough information is required for decisions and analyses to be made. If the information is short-handed the decisions will not be made based on the right amount of facts. (Mattsson, 2012)

Quality Aspects
Within the walls of a company, quality is often said to focus on delivering to the customer’s expectations and specifications. Such expectations and specifications can include to what extent the product is able to perform the intended task. Quality can be controlled with various methods, such as statistical tools and standardization. Another aspect, closely related to quality, is performance, which in turn focuses on the engineering being up to date and the tasks to produce the product being done correctly. (Miltenburg, 2005) It is not uncommon for different functions within a company to define quality in different ways. The Quality Assurance process includes maintenance of the current methods and aims. Commonly a purchaser can study the product, as well as how well the process and systems are functioning at the supplier. (van Weele, 2014)

Bergman and Klefsjö (2010) chose to distinguish the quality dimensions of goods from the ones of services. The quality dimensions considered to be connected to goods and services are listed on the next page. Some dimensions are similar to both goods and services, such as reliability. But the definition of reliability varies between the two. For goods reliability concerns how often a problem occurs and the seriousness of the problem. For services reliability concerns performance consistency in factors such as information precision, punctuality, and keeping to agreements. (Bergman & Klefsjö, 2010)
Quality Dimensions of Goods

- Appearance
- Durability
- Environmental Impact
- Flawlessness
- Maintainability
- Performance
- Reliability
- Safety

Quality Dimensions of Services

- Access
- Communication
- Courtesy
- Credibility
- Empathy
- Reliability
- Responsiveness
- Intangibles

Closely related to the quality dimensions is working with continuous improvements. Continuous improvements are said to be vital for a business survival and not stopping to improve, could mean ceasing to exist. Not only the product can be improved, but also the process and cost reductions can be made. Bergman and Klefsjö (2010) emphasize the importance of continuous improvement by stating that “it is always possible to improve products, processes and methodologies while using fewer resources, t.e. to achieve higher quality at lower costs” (Bergman & Klefsjö, 2010, page 44).

A common tool in Lean manufacturing is Kaizen, which means focusing on small improvements that may very well mean result in larger ones. Bergman & Klefsjö, 2010; Liker & Meier, 2006 Liker and Meier (2006) correlate Kaizen and standardized work by stating that standardized work is the base from which Kaizen should be done. Standardization of work is the reference for a step towards being able to improve the processes and eliminating waste and wrong doings. Furthermore, standardization of a process will also ensure the same output at all times and the variation in quality and quantity will not differ exceedingly. A common misconception is that standardization inhibits innovation, however authors such as Liker and Meier (2006) emphasize that standardization is quite the opposite. By working in a standardized way, a base for continuous improvement is set which advocates innovation. (Liker & Meier, 2006)

Forecasts

Forecasts are needed to be able to offer a shorter lead time to the customer than the actual production and acquisition time as a mean to predict the future Jonsson & Mattsson, 2003. There are different types of forecasts, both subjective ones, based on judgement and experience as well as customer surveys, and objective forecasts based on analysis of data Anupindi, Chopra, Deshmukh, Van Miegham, & Zemel, 2014. Depending on how far into the future the forecast is supposed to reach the more unreliable it gets, and then the forecast usually is more dependent on guesstimates and reasoning from people with good knowledge Segerstedt, 2008.

Forecasts usually have four characteristics that are important to be aware of, which are the following:

- Forecasts are usually wrong
- Forecasts should be accompanied with a forecasting error
- Aggregated forecasts are more accurate
- Long-range forecasts are less accurate

These four characteristics can be used to decide how much faith that can be out into a forecast and therefore subjective aspects should be added to quantitative models. (Anupindi, et al., 2014)
Ordering

How the quantities should be dimensioned and how often orders should be placed can be decided in multiple ways. The quantity can be fixed and the periodicity varying, or the opposite way around, or both can be fixed and both can be varying. Which method that is used depends on the demand, the inventory policy and what type of product that is bought. Three different methods of determining the order quantity are the Wilson Formula, Silver & Meal, and Wagner & Whitin. (Oskarsson, Aronsson, & Ekdahl, 2013)

The Wilson Formula is based on the assumption that demand is constant, each order is connected to an order cost, and that the inventory is based on the average level. Therefore, both the order quantity and the periodicity will be constant when using the Wilson Formula. The quantity is derived from the total cost curve and it is the minimum of the cost curve that determines the order quantity. How the quantity is determined can be seen in Appendix B - Equations, Equation 1. (Oskarsson, et al., 2013)

The Wilson Formula has some limitations due to its simplicity. For example, the formula does not consider discounts when buying large quantities nor that the capacity in inventory space, transportation, and that production errors may occur. (Oskarsson, et al., 2013)

The Silver & Meal and Wagner & Whitin methods are both dynamic methods taking the estimated need into account when deciding the order quantity. Silver & Meal compares the average monthly cost for the total amount of months in advance, that is possible to order for and when the average cost goes up the searching stops and the quantity is set, as is explained in Appendix B - Equations, Equation 2. The Wagner & Whitin method is similar to the Silver & Meal method but it optimizes the ordering cost for all periods to come with a known demand, as can be seen in Appendix B - Equations, Equation 3. (Oskarsson, et al., 2013)

Delivery

The delivery lead time of a product or article is the time from the receipt of an order to the delivery, depending on the lead time of all the activities performed before delivery. It is an important factor when planning material and it determines when an order should be placed. (Segerstedt, 2008) The delivery lead time depends on different aspects, such as if it is a produced article or a bought article. If the article is bought article is dependent on the delivery lead time of the supplier and the handling when it arrives. A produced product depends on both the capacity of all the involved operations and the current load. (Jonsson & Mattsson, 2003)

How good deliveries are performed can be measured in two ways – delivery accuracy and delivery reliability. Delivery accuracy is a comparison of how many deliveries are done at the promised time and how many deliveries that are done in total. It can be divided into how many orders that are early and late respectively as well. Another parameter which needs to be taken into consideration when studying the delivery accuracy is how new delivery times are agreed upon. Delivery reliability is defined by Jonsson and Mattson (2003) as the number of right products, in the right quantity that are delivered, but can also be defined, by the same authors, as the amount of orders with no remarks by the customer compared with the total amount of orders made. (Jonsson & Mattsson, 2003)
**Material Staging**

Material Staging is the process of ensuring that material needed for production is available before starting to produce or starting a certain operation. Jonsson and Mattson (2003) mention that there are three different methods for staging material. One way to material stage is to physically reserve material, so called physical staging, by placing it at a certain location within the storage area. This is a good method if the Enterprise Resource Planning System (ERP) is not trustworthy enough to show the correct inventory levels. However, this method creates a large amount of capital tied up and extra material handling processes. It also makes the production less flexible since it the material will be harder to switch or move. (Jonsson & Mattsson, 2003)

The other two methods for material staging are to check the inventory levels and reserve material within the system. The former method checks what is in stock and compares it to the demand. A reservation is then made in regards to the available material. The latter method rather checks the unreserved inventory and if the unreserved inventory is sufficient for the process, the process is started. Both methods are more flexible than the physical staging and it also possible to see if material will arrive in time for production to start as planned. However, the system might have uncertainties within itself that may cause problems. (Jonsson & Mattsson, 2003)

**Process Flow**

The flow of a process can be measured in different ways and the average inventory within the process and takt time, for example, can be calculated based on the flow time and flow rate. The flow time is the time a single product spends within a process and the flow rate, or throughput, is the number of units passing a specific point in the process per time unit. (Anupindi, et al., 2014)

The relation between the process inventory, the flow rate, and the flow time is defined through Little’s law, see Appendix B - Equations, Equation 4, and by having two of the measures the third one can be derived by using Little’s Law. (Anupindi, et al., 2014)

The ratio between the theoretical flow-time and the actual flow-time is called the flow-time efficiency and is a measure of how much extra waiting time that is added within a process. The theoretical flow time is the minimum amount of time needed, including some waiting time that is expected to arise within the process. Connected to the flow-time is the takt time which is a measure of how much time a process have to handle one unit. It is calculated by taking the inverse of the flow rate. (Anupindi, et al., 2014)

WIP is the amount of products that are in the process of being produced. They can either be within a process or waiting in line. The amount of WIP stands for a cost that can be compared to the cost of products in inventory. (Jonsson & Mattsson, 2003)

The capacity in the process flow is of help when making production plans. A common way of calculating the utilization can be seen in Appendix B - Equations, Equation 5. (Jonsson & Mattsson, 2003)

**Inventory and Safety Stock**

The benefits of having an inventory must be compared with the costs that arises when having material in stock. It is necessary to have an inventory available within the processes due to variability in the processes, to ensure that the production never stops. Inventory can be classified in an input buffer inventory, buffer inventory, and output buffer inventory. (Anupindi, et al., 2014)
The size of the inventory depends on how much is ordered at the time and when the order arrives. The reason for having an inventory of products, parts, or raw material differ between companies and there are different benefits that may be collected from having an inventory. One reason to have a large inventory is economies of scale. Another reason is to level out the production if the demand varies, by building up the inventory the low demand period and then reducing it when the demand is high. Two other reasons for having an inventory is to avoid possible stock-outs or increasing prices that might occur in the future. (Anupindi, et al., 2014)

It is common to analyse the Cover Time for the stock available, which can be various types of equations. One of these equations is the Inventory Turnover Rate, whose equation can be seen in Appendix B - Equations, Equation 6, which studies the relation between the value of the material flow during a studied interval compared with the capital found in the material flow, typically found in inventory. (Jonsson & Mattsson, 2003)

More often than not, there are uncertainties in both the demand and in the delivery lead time and therefore most companies have a Safety Stock (SS) to prevent the production to stop. How the SS is dimensioned varies, but there are some different alternatives to how this can be done. The SS can either be dimensioned based on the likelihood of not having a shortage during a cycle, defined as SERV1, or it can be dimensioned of how much of the total demand that can be delivered straight from stock, defined as SERV2. Both SERV1 and SERV2 are set as a percentage of the likelihood that the definition occurs and from there the safety stock is calculated. Both types of SS are based on the delivery lead time, the demand, and the deviations of both. The calculations can be found in Appendix B - Equations, Equation 7. (Oskarsson, et al., 2013)

Flexibility

Flexibility can be categorized into three categories depending on its focus area. When focusing on the ability to quickly react to changes in demand for different products and variants it is called product flexibility. The flexibility in this category consist of being able to adapt the production and material flow, which includes adapting delivery times, batch sizes and throughput times. A second category is the volume flexibility which focuses on adapting the produced volumes, without consideration taken to demand changes to different products. A clear correlation can be drawn to the capacity used within the process flow. For example, if the capacity used is low, it is easier to increase the production if the demand increases. (Jonsson & Mattsson, 2003)

The third category is delivery flexibility which takes into consideration the possibility to change the delivery times in accordance with changing demand. Factors which are important when working with the delivery flexibility are the delivery times to the company’s own production, throughput times, setup changes and batch sizes. (Jonsson & Mattsson, 2003)

3.3 Material Planning

The supply of material to a company can be seen in many ways. The material can for example be supplied directly from a supplier, from a distribution centre or a central storage, internally, at the company site. This creates vast options of how the material should be planned to arrive to the right place at the right time. (Oskarsson, et al., 2013) Some of the most common methods found in literature are described below and contain elements of both periodicity and quantity.
3.3.1 Reorder Point System

The Reorder Point System focuses on the inventory level and once the inventory level is below a certain quantity a call-off is sent. Oskarsson, et al. (2013) calculate the Reordering Point by studying the SS level together with the calculated demand during the time period which it takes for the order to be delivered. Segerstedt (2008) takes on another approach when calculating the Reordering Point and takes the equation one more step back, focusing on the service level in the production and considering other parameters. The Reordering Point consists of SS and the forecasts of the demand during the re-stocking time, as can be seen in Appendix B - Equations, Equation 8 and Equation 7. (Segerstedt, 2008)

For companies with a product that is dependent on the season it is not recommended to have a Reorder Point system, since the Reorder Point would need to be adapted continuously (Jonsson & Mattsson, 2003). Mattsson (2012) identifies two principle ways of working with Reorder Point Systems, those who review the system continuously and those who review the systems at given intervals. Most common are the systems that review at given intervals, which in turn affects the calculated lead times for the arrival of the material. Furthermore, by working with intervals the work is done more efficiently since the work has a clear structure as to when and where it needs to be done. (Mattsson, 2012)

Some of the characteristics of a Reorder Point system are that it is considered to be easy to understand, since it is connected to derived demand through forecast in the long run and it is suitable for products with independent demand. However, it is not possible to plan much ahead. Reorder Point Systems are commonly used for already finished products that need to be distributed, low-value material with a stable demand, and products which do not have a formulated demand plan. The flow of materials can be smoothened if the batch sizes are small and the throughput times are low, but also if no consideration is done in regards to capacity restrictions. (Jonsson & Mattsson, 2003) One of the major drawbacks of using a Reorder Point System is that a forecast for every individual product and component is needed and the relationships within the product structure are overseen, generating an unsteady flow and impeded possibility to foresee future deliveries (Segerstedt, 2008).

Jonsson and Mattsson (2003) summarizes the basic information needed for a Reorder Point System, as can be seen in Figure 10 below. The historical consumption, forecast, and calculation of gross material needed, together with the inventory level, all aid in deciding the consumption, the quantity in stock and the reorder point. The Reordering Point can be set as fixed if the demand and takt is steady over time, otherwise the Reordering Point system is recommended to be set as flexible. (Jonsson & Mattsson, 2003)

![Figure 10 Useful information for working with Reorder Point System (Jonsson & Mattsson, 2003).](image-url)
3.3.2 Base Stock System

The Base Stock System, also known as Periodic Review, focuses on restocking the inventory to a certain level at a periodic phase. This means the ordered quantities may vary from time to time. (Segerstedt, 2008) Jonsson and Mattsson (2003) look at the demand over the replenishment interval and the lead time together with the SS when calculating the ordering point to come up to the base stock level. Depending on the way the reports are done, the Base Stock System offers a possibility to warn the supplier if there are any upcoming changes in the future order quantities. One example of this is having the controls of the stock more often than at than the orderings intervals. (Jonsson & Mattsson, 2003)

Another advantage of working with a Base Stock Systems is the possibility to coordinate functions in order to, for example, make the transportation more efficient (Oskarsson, et al., 2013). To calculate the replenishment size, Segerstedt (2008) focuses on first calculating the replenishment level, followed by studying the average inventory available, and the deducting these two values from the average quantity ordered. These calculations can be seen in Appendix B - Equations, Equation 9.

The general information needed when working with a Base Stock System is shown below in Figure 11. There are some similarities between the Base Stock system and the Reorder Point system, which also the case when it comes to the advantages and disadvantages of the system. The Base Stock System is typically in environments with independent demand. There is no consideration taken to changes in the material need when planning the order points, which sometimes is a disadvantage. An advantage is that the Base Stock System does not need vast quantities of raw data to work, the smaller the batches and the shorter the lead times, the more effective is the Base Stock system. (Jonsson & Mattsson, 2003)

![Figure 11 Useful information for working with Base Stock System (Jonsson & Mattsson, 2003).](image)

3.3.3 Cover-Time Reviewing

Some of the drawbacks of Reorder Point Systems are taken into consideration when working with the Cover-Time Planning that rather focuses on time than on quantities. The production plan is generated and fixed until a certain point and if any changes are needed to be done, the plan is revised. Cover-Time Reviewing offers a flexibility where all products and components are considered. Segerstedt (2008) calculates the need to place an order in relation to the cover time which can be seen in Appendix B - Equations, Equation 10. (Segerstedt, 2008)

By working with the product structure Cover-Time Reviewing offers an understanding of the load projection and is also considered to be a proactive planning method since it suggests when there is a
risk of shortage in stock. Some of the characteristics of Cover-Time Reviewing are that it is an easily applicable method, especially since it allows for an understanding in the inventory levels and also urgency of placing an order. (Jonsson & Mattsson, 2003)

It is important to know the time between orders when using Cover-Time Reviewing and a common tool to achieve economies of scale is the usage of the Wilson formula, which in this case indicated when the order quantities have been established and the replenishment periods are studied. Since Cover-Time Reviewing is a visual planning method it offers a quick and flexible opportunity of re-planning if needed. Further, since the method indicates a natural pull-system, similar to Kanban, the capacity within the process flow is easily calculated. (Segerstedt, 2008)

Information needed when working with Cover-Time Reviewing to give an indication of production, capacity, and ordering the inventory levels must be known. The historical consumption, forecast, or production plan together with the gross material needed will then help to generate the cover time which in turn will generate suggestions of planned orders, arranged according to the customer demand, as can be seen in Figure 12 below. (Jonsson & Mattsson, 2003)

![Figure 12 Useful information for working with Cover-Time Reviewing (Jonsson & Mattsson, 2003).](image)

### 3.3.4 Material Requirements Planning, MRP

Material Requirements Planning (MRP) is possible to use when the production plans are updated continuously, a product structure is present, sufficient inventory exists, and the lead times are known. (Segerstedt, 2008) The basic principle of MRP is to create a plan as soon as there is gross demand for the produced product. (Jonsson & Mattsson, 2003) By working down the product structure a tree of components is created which in turn generates need for other processes. For the product structure, it is common to use the Wilson formula, Silver & Meal, Wagner & Whitin or another method to decide in-going quantities. (Segerstedt, 2008) When working with MRP input in the process can be seen in Figure 13 on the next page, which allows for a good overview of the correlations between time and components. (Jonsson & Mattsson, 2003) Within this information the production plan, together with product structure, inventory levels, lead times, and order quantities, operation data generates a list of when to start purchasing and manufacturing together with a forecast to suppliers and the capacity used. (Segerstedt, 2008) The availability of information allows for planning orders far into the planning horizon, as long as there is a forecast available. (Mattsson, 2012)
The use of pegging allows the planner to quickly identify what parts of the product structure that are affected by, for example, a late delivery or a quality issue. A possible remake of the plan could result in many changes. Plans redone in the nearby time period have a greater impact on the production than those who are not near in the future. To reduce the possibility to remake the plans, MRP often uses time fences to easier structure when plans can be changed and not. The time period when plans are not allowed to be changed is said to be frozen, whereas time periods when the plans can be changed are considered to be flexible, and sometimes the system itself is allowed to make changes during this period. Between these two time periods is the semi-frozen time period, during which no major changes are allowed. (Jonsson & Mattsson, 2003)

The characteristics of MRP include that it is considered to be more complex than earlier described methods as a consequence of its usage of parameters such as time and product structure. Planning towards a known demand, or forecast, is the aim of the method and at the same time deliver as late as possible, indicating a usage of JIT. The more uncertainties the less advantage MRP has over the earlier described methods. (Segerstedt, 2008)

3.3.5 Internal Supply Methods

When supplying the production with material there are different ways to do it and which system that is more suitable depends on the type of product and what material that is to be used. Some of the systems that may be used for material supply are the same as the methods for ordering material from a supplier, such as Reorder Point system and Base-Stock Review. (Oskarsson, et al., 2013)

The type of product that is produced will affect how the planning and material supply are designed, but also how much information that is available about the final product. For all products, a product material structure can be created that shows what components it consists of, but it can also show where the Customer Order Point (COP) and the Decoupling Point (DP) is located in the product structure. The COP and DP are both related to how much information about the final product that is available and if a customer has put an order or not. The COP is the point in the product material structure when the production is done towards customer order instead of a forecast. The DP usually is at the same place as the COP, but it can be placed earlier in the structure than the COP. The DP marks the place in the product material structure when the production is done based on real facts instead of towards a forecast. (Jonsson & Mattsson, 2003)

A production process can be categorized into five different types of manufacturing, depending on what information it is based on. The different categories are make-to-stock, assemble-to-order, make-to-order, and engineer-to-order. Depending on which category a company uses within their production different amounts of information about the final product is available at different points in the process and the production plan will need to be adjusted according to the information available. Figure 14
below shows a comparison between how much information is available depending on what category that is used. (Jonsson & Mattsson, 2003)

Figure 14 Degree of information from order intake to delivery for different types of production (Jonsson & Mattsson, 2003).

Kanban System
Kanban is a Lean tool from the Lean philosophy and works as a replenishment system. Even though Kanban can be considered to create waste due to the extra work and inventory involved, it is useful to avoid the need of scheduling all the material piece by piece, and in that sense Kanban can be said to reduce some waste. (Liker & Meier, 2006) In a Kanban system, a Kanban Card is placed within the material and when it appears it is sent to the supply and the article is replenished (Oskarsson, et al., 2013).

Kanban works with the demand and in order for a Kanban system to work properly the demand needs to be even, or the production needs to be steady at least. If the pace of the production is even, Kanban is a possible way to supply the production with material, both from suppliers and from stock but more decisions are needed to be made. The following categories all regard how the Kanban system should be designed and some decision categories are crucial to make the system a beneficial one. The lot size decides what type of container that is chosen for the article and decides the Kanban Order Quantity. For the Kanban Order Quantity there are three options; standard order quantity, one for one, and full Kanban lot size. The formula for deciding the Kanban lot size is shown in Appendix B - Equations, Equation 11. (Louis, 2006)

The Kanban system should be maintained and it should also become part of the daily routine to work with it. If the demand rate changes the Kanban system needs to be refigured to fit the new pace. It is also important to have the environment around the Kanban and the material handling in mind since it will affect how it will work and if waste will be reduced. (Louis, 2006)

Two Bin System
A two-bin system is similar to a Kanban system, but a two-bin system does not use cards. The system includes two bins of material and when the first one is empty it works as a signal for the internal logistics staff to replenish with new material. It is a quite simple system, but the size of the bin needs to be able to have enough capacity for the second bin to not run out when the first one is replenished. (Oskarsson, et al., 2013)
Kitting
Kitting is a replenishment system where all material needed for a product, or part of a product, is delivered as a set to the production line as close to the time it is needed at, as possible. A Material and Production Management system is a good tool to use for kitting to work, since it will break down the material needed to lists of components. (Oskarsson, et al., 2013)

Sequencing
Sequencing is often used in industries where the products are adapted to the customers’ choices and the variance is great. Sequencing means that material is delivered to the production line in the same order as the assembling product is and then each unique part is placed on the right product. (Oskarsson, et al., 2013)

3.4 Production Systems
Production systems are usually divided into three levels of control, Strategic control, Operational control, and Execution control. Each level of control can be identified with a system used throughout the production with different purposes. For the strategic control an Enterprise Resource Planning (ERP) system is most commonly used. This type of system builds on MRP and MRPII systems, depending on what the strategy of the plant. The ERP system is connected to a Manufacturing Execution System (MES) which handles operations and the planning of the production. The MES is in turn connected to a Supervisory Control and Data Acquisition (SCADA) system that collects data from the equipment used and as the name implies monitors and controls all processes within the manufacturing. The collected data is sent to the MES and used there to manage the production. (Romanov, Romanov, Kharchenko, & Kholopov, 2016) An overview of the systems and the connection between them is shown in Figure 8 below.

![Figure 15 The different systems and the corresponding level of control (Romanov, et al., 2016).](image)

3.4.1 Enterprise Resource Planning
ERP systems were developed during the early 1990s as a way for organizations to become more competitive and effective in their processes. An ERP system allows for seamless information sharing that speeds up the processes. (Ganesh, Mohapatra, Anbuudayasankar, & Sivakumar, 2014) ERP systems have also allowed organizations to collect more information in real time. (Sia, Tang, Soh, & Boh, 2002)

The system is usually built up in modules for each department within the organization, for example production management, finance, and procurement. All the modules are then connected to one another to be able to access information faster. (Ganesh, et al., 2014)
An ERP system makes an organization more productive by both helping the organization collect relevant information at the right times, as well as applying a best-practice to the processes. The system allows for automation of processes which makes it possible to lower the need for humans to be involved in mundane activities, and to react faster upon changes in, for example, demand. (Ganesh, et al., 2014)

3.4.2 Manufacturing Execution System
The MES is closely related to MRP systems that peaked in use during the 1970s and 1980s. Then a non-reactionary approach was embraced throughout the industries, and the MES was able to help a plant monitor the processes more closely and in a more automated way than before. (Mehta & Jaganmohan Reddy, 2015)

Nowadays, MES works as the connection between the SCADA system and the ERP system within production. This is the layer of systems used to manage the production and all daily operations at a plant. The system is connected to a SCADA system and the two systems exchange information regarding the processes and the status of all the operations. However, it is the MES which executes all work orders and where the planning is done. (Mehta & Jaganmohan Reddy, 2015) The real-time information from a SCADA system is needed to be provided to the MES to have open and closed-loop control of the processes. (Naedele, Chen, Kazman, Cai, Xiao, & Silva, 2015)

The three functions the MES is used for are Production Planning, Operations Management and Production Management, and the system is controlled by the users. The users may be anyone from operators and engineers to management, all using different tools in the system depending on their responsibility. (Mehta & Jaganmohan Reddy, 2015)

The MES usually follows the standard ISA-95 which states that a MES should both provide a support for management of security, information, regulatory compliance, and information, as well as provide links to work orders, shipping, quality controls, maintenance, scheduling, and receipt of goods. (Mehta & Jaganmohan Reddy, 2015)

There are multiple benefits that come from using a MES not only reduction of waste and being able to increase uptime, but also to track costs of different sorts. (Mehta & Jaganmohan Reddy, 2015) By also storing historical data, and keeping prognoses and future events in the MES, can analyses and earlier warnings be executed respectively. (Naedele, et al., 2015)

3.4.3 Supervisory Control and Data Acquisition
SCADA systems have been implemented since the 1960s and are widely used within industries and manufacturing companies. The system has multiple functionalities, but the main ones are to collect a large amount of data from the equipment and to process and analyse it. (Mehta & Jaganmohan Reddy, 2015)

SCADA is a system consisting of Remote Terminal Units that are connected to all the equipment and sends information about their status and usage to a central computer. The Remote Terminal Units are connected to the central computer through a wide-area communication system, usually the internet or an intranet. This is all complemented with an interface for the operators to be able to access the system. (Mehta & Jaganmohan Reddy, 2015)

The collected information is usually displayed within the production to inform the operators about the status of the machines or other Key Performance Index (KPI) computed from the collected data in real
time. This interface display can be done in different ways, typically operational or diagnostic, or a combination of both. What is displayed can be decided by the operators and adjusted to the processes and the needs. (Mehta & Jaganmohan Reddy, 2015)

A SCADA system can also be programmed to alarm when certain levels of data is detected. This is one of the main functions of the system, since it is impossible for a human to go through and process all of the data in an efficient way. The spans and thresholds need to be established with care and precision to fit the needs and to not alarm too frequently. If the system alarms too frequently the operators will not respond as they should, and if it does not alarm frequently enough, issues will be neglected and which in turn may escalate to bigger problems. How the alarm should be signalled may be adjusted as well. It might be flashing light or an audio signal of some sort, or it may be an email or SMS to all concerned parties. Information regarding alarms can be stored in files to be able to follow up on certain indicators of how different shifts work or how the production performs over time. (Mehta & Jaganmohan Reddy, 2015)

3.4.4 Business Intelligence

BI is a broad term that is passed on the process of transforming data to information, and by using the information make decisions and act upon those decisions (Turban, Sharda, Delen, & King, 2013). Loshin (2013) states that BI provides multiple analytical tools which can be used throughout the organization to maximize the benefit of all stakeholders and optimize the business processes. These analytical tools range from reports to predictive models and help answering the questions What?, Why?, What if?, What next?, and How?. These five questions are increasingly more complex to answer and thereby the tools become more complex as well. In Figure 16 below the type of tools needed to answer the questions are shown. (Loshin, 2013)

![Figure 16 The tools used to answer the different types of questions when using BI (Loshin, 2013).](image)

The tools at the beginning of the spectrum in Figure 16 above provide an understanding of the current state. As the scale prolongs, it involves a deeper understanding for why the state is as it is and later on analysis of possible future states. On the far right hand side of the spectrum tools helping the user to know what will happen in the future and how the processes should be run as optimally as possible. (Loshin, 2013)

However, even if there are different types of BI tools, it is built up in the same way and is composed by four parts; a data warehouse, business analytics, Business Performance Management, and a user interface. (Turban, et al., 2013)

The data warehouse contains data, mainly historical data, but nowadays current data can be stored there as well and used in the analysis. The data is organized to be manipulated by the users in an easy way. To analyse the data in the warehouse different tools and techniques are possible to use and they can be categorized into two groups. The first being Reports and Queries, and the second Data, Text, and Web mining and other sophisticated mathematical and statistical tools. The first category is composed of different types of reports and ways of displaying data, but also allowing the user to zoom in on details. The second category includes data mining and searching for patterns and confirming these mathematically to become predictive. (Turban, et al., 2013)
BI can be used within all functions within an organization to analyse the strategic decisions to how the processes flow. In regards to material and material flow BI can help with inventory control by assisting the decision making of what products to keep in stock and when to order. It may also help with distribution analysis and how material should be distributed among units to minimize costs and help to ramp up the flows evenly. (Loshin, 2013)

To be able to support decisions made within manufacturing Operational BI can be used. Operational BI is using analytical tools and capabilities in order to control the processes creating value within an organization to have continuous improvement within the processes and execution. It may provide organizations with decision support to managers within industries. (Hänel & Felden, 2013)

It is important, though, to keep in mind that even if all the needed functionalities and databases are in place, the interaction between IT and the personnel is crucial to achieve the desired effect (Elbashir, et al., 2013).

3.5 Industrie 4.0

There are many terms coined in connection to Industrie 4.0. For instance the components, products, and processes of a Smart Factory are closely related to IoT and Cyber-Physical Production Systems. Cyber-Physical Production Systems contain a higher degree of connectivity between factory components such as machines and computers within the production system, than Industrial IoT. (Shariatzadeh, Lunholm, Lindberg, & Sivard, 2016) Some of the possible advantages of having an increasing amount of digitalization within a company include better knowledge of demand and stock fluctuations, and also a better positioning against the competition (Deloitte AG, 2015).

Cyber-Physical Production Systems consists of four cornerstones, the Physical World, Data Acquisition, the Cyber World, and Feedback and Control as can be seen in Figure 17 on the next page. The Physical World is doing the physical transformation of a product, resulting in generation of data which can be used for analysis and improvements. The state variables connected to the Physical World are factors, both internal and external, which may affect the production, for example demand. Where the variables are coming from is important for the later steps and further analysis, The Design and Control parameters are closely connected to the traceability of the data. (Thiede, Juraschek, & Herrmann, 2016)

Data Acquisition requires data, estimations and indirect measurements, to function. If the measurements are to be done in real time or during specific intervals is very much up to the process taking place. In other words, if the data is used to control a machine a real-time update should be applied. Another point which may be of interest is not always measuring at the same spot, in other words increasing the measuring points (Thiede, et al., 2016)

The third cornerstone, the Cyber World, is a representation of the process and production system. The use of qualitative data and the application of KPIs allows for manually handling the data within in the system. Thiede, et al. (2016) suggest that the models can be based on data and regression analysis, physical, numeric or discrete events. Models should be used to process the data at a fast and reoccurring state and adapted to the users’ needs. (Thiede, et al., 2016)

Feedback and Control, the fourth corner stone, allows for interaction through humans to make improvements. As mentioned before, transparency is vital throughout between the cornerstones to allow for analyses done by humans. Furthermore, by having this transparency and continuous flow of
data the users are offered support in making decisions and allowing for automatic control which may send out warnings when a deviation occurs. (Thiede, et al., 2016)

![Figure 17 The four cornerstones of Cyber-Physical Production Systems - the Physical World, Data Acquisition, the Cyber World and Feedback/Control (Thiede, et al., 2016).](image)

What Thiede, et al. (2016) also emphasize is the importance of integrations between various systems and the users. Furthermore, their model (Figure 17) studies the relations between connectivity, learning factories and digital manufacturing as important steppingstones in Industrie 4.0. (Thiede, et al., 2016)

Similar to Thiede, et al. (2016) Deloitte AG (2015) has chosen to summarize Industrie 4.0 into four main categories, consisting of the characteristics that are applicable to the terminology. The first one of these categories include the vertical networking of smart production systems, for example multiple functions being able to use the same set of data. This can be done by storing information and data in cloud based applications, allowing for analyses and data management for all the functions having access to the information. The processing of enormous quantities of information, and also the gathering and analysis of it, allows for new insight and also support in decision making. Examples of smart production include sensor technology that allow for monitoring and autonomous decision making. The second characteristic if the horizontal integration of the global value chain network. This indicates that all information available through the life cycle of the product, and factory, can be stored. This allows for transparency within the information flow and also for deviation control, especially if one common database is used. Through-engineering across the entire value chain, the third characteristic, focuses on the availability of the data and the life cycle management. The final characteristic, acceleration through exponential technologies, focuses on the learning organization in itself with the help of tools such as Artificial Intelligence and cognitive and autonomous systems.
Emphasis is put on the IT infrastructure since many companies today lack the basic conformity to directly transfer to a more Digital Factory. One aspect that is often missing is the communication network between systems and also the knowledge of how the network is connected. Knowing this could allow for faster information transfer and thereby also faster availability of data and decision making.

The transfer of information is something that Shariatzadeh, et al. (2016) studied when focusing on the integration of Digital and Smart Factory. The Smart Factory feeds the Digital Factory with information through IoT and Industrial IoT, generating a need for standardized communication such as Open Services for Lifecycle Collaboration. Open Services for Lifecycle Collaboration helps software tools to share information between each other. Shariatzadeh, et al. (2016) state that transferring information from a Smart Factory to a Digital one needs to consider three layers, or steps. These layers consist of data transfer protocols, data representation and presentation, and finally semantics and understanding of the data. How the communication between each layer is formulated is very much up to the architects of the system. (Shariatzadeh, et al., 2016)

Feeding on the information from the Smart Factory and IoT, the Digital Factory creates either a model of a factory or a reflection of a real factory (Shariatzadeh, et al., 2016). Having a Digital Factory allows for simulations of the entire life cycle of the factory, similar to the lifecycle of a product. Adding to this simulation are tools which help in studying the data outcome in each and every work step, data which should be stored in a large database available for the entire factory and its users. This will allow for an in depth understanding of, for example, an investment and changes in production plans. In that sense the Digital Factory poses as a combination of digital models and applications which work with processes, logistics, and factory planning as well as ERP, operations, and improvements. The physical layout of the factory can be studied, together with the material flows and other logistical requirements. (Almeida & Azevedo, 2011) Further, having a digital industry allows for a visualization of the whole supply and business value chain, something which could prove useful when studying simulations and making decision models (Wikner, et al., 2016).

Américo and António (2011) created a Factory Templates in regards to Digital Factories. Factory Template is defined as a model with an integration of product, factory, and process life cycle, taking into account internal and external factors such as good practices. Factors which must be included in the framework are:

- Industry best practices
- How processes operate together with the information needed to function and how it can be analyzed
- What reporting is needed for different functions and processes
- What information that needs to be shared between different functions and analysers related to this
- How data from various sources can be used to study KPIs

The connection between these factors is equally important. Furthermore, learning is central to the concept, both from experiments, experiences and best practices. (Almeida & Azevedo, 2011)

With today’s data structure and data gathering it is often hard to gather and use data in real time. Lee (2017) points out that this gap is not only from the side of the simulation software, but also from the production software itself since many factories do not have the base for making predictions and
simulations. It is therefore important to find the connection between the physical system and the cyber system in order to make full use of the data, and especially the real-time data, available. Having this interaction would allow for risk analyses, what-if manufacturing and scenario-based manufacturing as well as decision making support with the use of real-time data. (Lee, 2017)

The connectivity between different functions and how to structure the information is something which has interested Wikner, et al. (2016) who have studied the connection, or flow logic, between the business value and industrial digitalization. According to them, having a structural platform with a given flow logic, where the structure and sorting of the available information, is vital. Having this allows for physical and information systems to integrate and generate value is made and, therefore, how digitalization should be conducted. Since every company is unique and there are not many general solutions available on the market today companies should look inwards to study their specific flow logic to be able to use digitalization for decision making. One of the possible gains according to Wikner, et al. (2016) is to help in the decision making within various processes of the company. However, care and logic, must be used when dividing the company into different processes and the correct level of information must be applicable to the process in questions. As for the decision making, one of the possible benefits of integrating business value and industrial digitalization is that more and more operational decisions can become autonomous, giving more time for more strategic decisions. The autonomous manufacturing systems should be able to capture, share, and exchange information, as well as being able to make decisions. As for the more strategic decision making, the gathering and analysing of data allows for, for example, visual tools in decision making. Wikner, et al. (2016) also summarized some of the more important aspect to take into account when studying Digital Factories. These aspects include guidelines that should be focused upon such as that digitalization should be seen as a tool that needs to be structured in order for a flow logic to be in place, something which is especially needed since the structure of applying digitalization is not fully formulated. (Wikner, et al., 2016)

How to use the collected data should be known, even if there is a large set of data. The analysis can be done for storing logistics knowledge in a repository, making decision with real time data, and making predictions based on knowledge. Lee (2017) and Almeida and Azevedo (2011) study the concept of using data prediction and emphasize the importance of having traceable and historical information in order to make predictions even for the Digital Factory. There is a difference between forecasting tools and performance estimations. The former is only used to predict the future, whereas the latter tries to study the values of the past, present and the future and making predictions in regards to these values. By continuously studying and estimating the performance of the factory, warning signs may be received earlier, better feedback regarding the processes and KPIs, and simulations of decisions may be done. Furthermore, having the historical data about the factory and production put in context with market demands, economic factors and industrial factors further help in decision support. (Almeida & Azevedo, 2011)
4 Current State

The current state is presented below and all assembly processes in Södertälje are described as well as the final assembly in Zwolle based on the Order to Delivery Process established at the start of the chapter but with a standpoint in the material planning. In the chapter regarding the assembly lines in Södertälje, the Final Assembly, Engine Assembly, and Axle and Gearbox Assembly are described while for Zwolle it is only the Final Assembly line located there. Each case is built up by describing the different functions involved in the material flow in a chronological order. The functions described are Purchasing, Production Planning, Material Planning, Material Handling, and Internal Logistics.

As a complement to describing the functions, the production systems at Scania are described as well to give the reader an understanding for how these are built up and how they affect the processes. Some ongoing projects that are relevant to the material flow and data information are described as well.

4.1 The Order to Delivery Process

The Order to Delivery process at Scania consists of five main steps as can be seen in Figure 18 below. The first step is the customer placing an order, followed by the allocation of the production by the CPP, the Production Process itself, outbound and distribution of the finished product and then invoicing of the product. (Johansson, 2013)

Complementing the Order to Delivery process is the Production Process, also seen in Figure 18 below. (Johansson, 2013) CPP is done centrally, as is the case with Purchasing, while the production and material planning and the internal logistics is done individually by each PRU. Each part will be described further in this chapter.

There are various systems used in the production and planning at Scania which will be described later in 4.6 Production Systems at Scania and an overview is given in Appendix C - System Overview.

![Figure 18 Global Processes for Order to Delivery (upper arrow, adapted, Johansson, 2013) and the focus area of the study.](image)

4.2 Central Production Planning

The CPP monitors the total capacity available at the various PRUs at Scania. The CPP creates plans for each PRU of what they are expected to produce during each production period. One month consist of, on an average, four production periods, generating a frequent update of how much needs to be
produced. The distribution of customer orders is done according to some restrictions. For example, Södertälje is the only site which produces the NCG (Next Cab Generation).\(^5\)

The process of calculating the Gross Demand originates from Distributors who regularly send in their 12-month forecasts based on each distributors expected and made sales and is done in the system Adaptive Gross Demand Administration (AGDA). Figure 19 below represents the work done continuously by CPP, a process which is repeated once a month and lasting for a time period between two and three weeks. The aggregated demand offers information for analysis, such as volume, stock level, coming product changes, and coming price changes analysis. \(^6\) After the analysis is done CPP sends out two sets of programmes – Proposal and Decided. The Proposal programme is sent out one week prior to the Decided program and consists of suggestions which each PRU gets to study and plan according to. The Decided programme gives the takt which is needed to supply the customer needs. \(^7\)

\[\text{Figure 19 The CPP process for generating Gross Demand originating from Distributors through to the setting of a production plan.}\]

The proposal programme is divided into two, the first one being for the market demand where each PRU is compared to the calculated market demand. The following Proposal is a Production Proposal which makes a suggestion of the production volumes, production calendars, and the operational rates at each PRU in order to produce the expected volumes. The Production Proposal is then evaluated by each PRU and compared with the production capacity together with limitations and flexibility options, lead times, resource and material availability, as well as the global allocation. If the Proposal is accepted by for example purchasing, production planners, and workshop technicians the plan is set to be Decided. The Decided production program offers information for the Gross Demand with information such as a decided production program, a mixing forecast and as well as a component demand. This information is also forwarded to the suppliers of Scania as a forecast.\(^6\)

The process described in Figure 19 focuses on the long term planning, while plans for the short term are done in a different way. The main information input and output used by the CPP, together with one of the systems used, is shown in Figure 20 below.

\[\text{Figure 20 Main information input, output and systems used by the CPP.}\]

\(^5\) Production Planner 1, personal communication, 2017-03-08
\(^6\) Central Production Planner, personal communication, 2017-04-03
\(^7\) Production Planner 2, personal communication, 2017-03-13
4.3 Purchasing

The purchasing function works in teams of three; Commodity Purchaser, Project Purchaser, and one person responsible for Supplier Quality Assurance. These three are responsible for a product segment and to establish contracts, maintain the current contracts, and ensure the quality of the products. The main information input and output used by Purchasing, together with the systems used, is shown in Figure 21 at the end of this chapter.

Once a new article is decided to be used in production all possible suppliers get a Request for Quotation and then offers from suppliers are sent to Scania. If it is a new product that is going to be purchased, the offers are evaluated by the Project Purchaser, otherwise it is the Commodity Purchaser who evaluates the offers. One offer is chosen after considering the quality, delivery, and cost of the supplier and presented to the Sourcing Board and they decide if the business case will be approved. The Sourcing Board consists of managers and directors from the whole Volkswagen Group. If the interests of the Volkswagen Group is not considered a business case is likely to be rejected. Since purchasing is a central function, many functions are in contact with them. Some of these functions include the MPs who regularly give feedback regarding quality and other aspects regarding the suppliers and deliveries, but logistics functions also contact purchasing when contracts are made and in the continuous work with the supplier. Various functions give feedback regarding requirement specifications.

A purchase is done based on the yearly demand within production and then the MPs do call-offs from the supplier. The yearly demand is based on a forecast that is given to the purchasers in MATRIS. The purchasing department also use the systems AROS for keeping track of all articles used within production and Sourcing Tracking And Reporting (STAR) for sourcing provided by Volkswagen Group. A fourth system used is Material Control (MC), but only with the general login, to study the call-offs made by the MP to the supplier.

eQuality is used to follow up quality issues. Another system, FRAS, is also used to follow up on deviations regarding quality. Delivery performance is followed up as well as how the order quantities have kept to the contract. Having the possibility to react further in advance upon increases in quantity call-offs could mean cost savings since contracts could be renegotiated to lower costs for Scania. Being able to lower costs is of importance to Purchasing since it is one of the most important KPIs.

To secure the quality of all the purchased products, and the processes, the suppliers need to pass a quality check before delivering products to Scania, where documents and product samples are sent from the supplier. This is called Production Part Approval Process (PPAP) and if changes are done to the design or process of the product it needs to be approved again. If the PPAP is not approved, the MPs should not order parts form the supplier. If orders are placed anyway, Scania cannot claim defects of the product. For a new part, it takes about fourteen days to get a PPAP approved, depending on the complexity of the product.

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8 Supplier Quality Manager and Purchaser, personal communication, 2017-03-14
9 Assignment Manager, Purchasing, personal communication, 2017-03-09
4.4 Production at Scania, Södertälje

The production site in Södertälje is one of Scania’s largest and the main assembly of engines and gearboxes are located there, including a final assembly line for trucks and one for buses.

The Final Truck Assembly line (Chassi Assembly) in Södertälje is currently the only PRU which assembles the NCG, released in August 2016. The assembly line has been through some changes to match the new truck and new articles have been introduced but the basic structure of the assembly line has not changed much. The overall structure of the assembly line is divided into four main lines, each focusing on specific parts of the truck, which in turn are divided into twelve Functional Areas. Since the assembly line is still being improved around fifty trucks are produced each day, however, there is a total capacity of sixty trucks per day. The buses also have an assembly line which is separated from the truck assembly, and has an average of eleven buses produced each day.\(^\text{10}\)

The first part of the bus assembly line consists of assembly of the frame, which is customer specific from the start. After the frame assembly, the cabling is set. Every cable is customer specific and marked with a chassi number. The assembly line is then followed by assembly of front, rear, and support axle, as well as stabilizer and engine, amongst other components. Since the body of the bus itself is not assembled by Scania some tubes and cabling are for later, external assembly lines, and not all are needed for the function of the bus. The takt is closely monitored and set in relation to customer orders to reduce waste such as waiting time and too large buffer stocks. If needed the takt time can be regulated with the workers working hours. Throughout the production line visual tools are used, such as red and yellow markings on paper. These colours indicate if the material needs to be supplied often, red, or if the consumption time is slower, yellow. (Scania CV AB, 2015a)

As in the case with the bus assembly, the truck assembly starts off with the assembly of the frame, cabling, and pipes. Pre-assembly is done for some components such as axles and gearboxes, as well as engines, which are assembled later. At the end of the truck assembly line the cabin is assembled in sequence. Both finished trucks and buses are tested before they leave the workshop. The layout of the assembly lines allows for logistic trains to transport material between storage and its position on the assembly line. Generally, the articles are divided into three categories; batch-, kit-, and sequence-articles, but two bin systems are used as well. (Scania CV AB, 2015a)

\(^{10}\) Study Visit at the Chassi Assembly, 2017-02-21
Engines are assembled at Scania, Södertälje, at Scania Engine Assembly (Engine Assembly). The assembly is done to order with a specific customer in mind for trucks, buses, and Industrial and Marine (IM) purpose. It is mainly the European production that is supplied, but some engines are also sent outside of Europe. The structure of the engine line has changed over the years but the main functionality is in the straight assembly line which not only helps the flow of the engines but also the material supply. The logistic train which supplies the material is takted with the assembly takt with kits, batches, and sequenced articles. The engine assembly lines start with marking the cylinder block with a specific customer and chassi number. Parts of the line is made up of a stop-and-go flow according to the takt time. At the end of the engine assembly lines the flow is continuous, meaning the engines are moving while being assembled. (Scania CV AB, 2012) On average 290 straight engines are produced daily, of which twenty are IM engines. The base takt for the V8 engines is 44 per day.  

As in the case with the Engine Assembly, the axles and gearboxes are assembled to order but at Scania Axle and Gearbox Assembly (Axle and Gearbox Assembly). Parallel with the main line are pre-assembly line which supply components. The supply of material is done with flags which mark when a refill is needed. (Scania CV AB, 2015b) The output assembled daily varies, but as a base around 290 rear axles and 800 axles are produced on the two lines in the production per day.  

Central to the assembly lines at all assembly sites is that it is important that the right component is at the right place at the right time. Furthermore, the supply methods towards line are quite similar, with the use of visual signals and planning in combination with two bin systems, sequencing, batching, and kitting. (Scania CV AB, 2012; Scania CV AB, 2015a; Scania CV AB, 2015b)  

4.4.1 Production Planning  
The PPs base their work on the allocated orders from CPP. This means a certain amount of buses, trucks, engines, and axle and gearboxes, should be produced during each production period according to customer orders. As mentioned earlier, each PRU has restrictions with regards to what they are able to produce. Furthermore, there are rules for the sequence order in the assembly lines, called mixing rules, which also set restrictions. Nevertheless, the work of a PP is quite similar at the different PRUs at Södertälje. The PPs work with backward scheduling with regards to the finishing time of a product.  

Central to the production planning is Status 1 and Status 2. Status 1 is the signal which indicates when the mixing can be started. The process of mixing is done in PRAL and then the assembly sequence is decided in accordance to mixing rules. The mixing rules are restrictions regarding the order components may be assembled. Once the mixing is finished, another system, Scania Production - Adaptive oRder allocaTion and bAlancing (SPARTA), starts working which also starts the Status 2. This system either accepts or rejects the mixing made by the PP, and if accepted, breaks down the product structure and the information is sent to MA. The system Prossess is also used at all the assembly workshops to support the quality and after line production amongst other things.  

Since rescheduling does occur, the plan made in PRAL and SPARTA is not always followed. Rescheduling can occur due to changes in customer specifications, construction, preparation, assembly as well as due to lack of material. When a rescheduling is done, various functions are contacted, such as internal  

11 Production Planner 3, personal communication, 2017-03-14  
12 Production Planner 4, personal communication, 2017-03-13
logistics, team leaders, and MPs, to see if the change is possible. If there is a larger change that needs to be done, a product can be darkened, meaning the product is taken out of the assembly line. The reason for bringing a product out of the assembly line is mainly to avoid stops in the production due to material shortages or defects on the product. The reliability on the systems available is large, and sometimes faults are detected in other functions systems which affect the assembly line. One example of this is that the balance found in the systems used by the MPs is not reliable enough.

To match the production level with the incoming orders, the production planners have the option to let the workers work a bit extra some days and less other days. This is called Scania Flexible Workhours (SFA) and it is an agreement between Scania and the union. This is especially useful if the production is lagging behind and there is a need to catch up.

Since the PP at the Chassi Assembly receive the final assembly time of a vehicle they are the first ones to receive the plans from CPP first. Once the planning is done at the Chassi Assembly, other PRUs such as the Engine Assembly and Axle and Gearbox Assembly obtain their final times for their assembly lines about four weeks in advance to when it needs to be at the Chassi Assembly or at another customer. This means that the PPs at the Engine Assembly and Axle and Gearbox Assembly are dependent on the planning at the Chassi Assembly. However, there are two exceptions to this – gearboxes produced for MAN at Axle and Gearbox Assembly and IM engines at the Engine Assembly. The MAN orders are planned separately. The IM engines, on the other hand, are considered a finished product once the assembly is done and therefore planned separately from the normal assembly flow. However, the assembly of the IM engines is done on the same line as the other engines with a few extra stations at the end.

The PP at the Chassi Assembly are divided up into four areas consisting of the Development Assembly Line, truck assembly, bus assembly, and Knock-Down Assembly (KD). Parameters that are followed up on include revision of the mixing rules, number of re-schedulings done, and delivery precision. At the Axle and Gearbox Assembly the division of work is done differently by separating the planners into green and red planners, meaning planners responsible for means long term and short term planning respectively. The red planners are responsible for the axle and transmission assembly done in the coming one to two weeks and the green planners are responsible for the planning three weeks ahead and further. Much of the continuous work is done in MS Excel, for example control of the takt time for the assembly line and buffers which are then used in the Mona Systems. Some of the parameters that are followed up upon are delivery precision, production status, amount of components out of sequence and why, and what is currently being produced. As for the case with the other PPs there is much communication with other functions, such as logistics and material planning. Parameters are often revised, such as the mixing rules in the system.

At the Engine Assembly a Compressed Plan and Displacement are used to fill the capacity and level the production. Compressed Plan means that the capacity is used to maximum, even if the engines are not planned to be done until later. Displacement means that for a certain number of days at the end of the planning horizon the order book may not be full yet, but the forecast shows a higher demand, and then a plan for the higher demand is created. If more orders are still wanted the PP at the Engine Assembly contacts the CPP to be allocated more orders that were not originally in the plan for the period. As in the case with the other PPs in Södertälje, which overall is similar to each other, the work

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13 Translated from SFA, Scania Flexibel Arbetstid
is continuously followed up upon in regards to production status, sequence changes, and also follow up of material from the component workshops. Following up the material from component workshops is part of the PPs role as is the case with the PP’s at the Chassi Assembly being responsible for the procurement of Scania material, such as engines, cabs, and axles and gearboxes, to the Chassi Assembly.

Figure 22 Main information input, output and systems used by the PPs in Södertälje.

4.4.2 Material Planning

The MPs at Scania are responsible for the procurement, delivery, and management of materials needed in the production. The tasks of an MP are quite standardized, however, there are some differences between the procedures at the Chassi, Engine, and Axle and Gearbox Assembly in Södertälje. The main information input and output used by the MPs in Södertälje, together with the systems used, is shown in a general figure in Figure 23 at the end of this chapter.

The tasks of an MP have many factors in common. Commonly the daily tasks of an MP include checking for shortage warnings and open orders. Open orders is defined as when material has been ordered to line without success since there was not any material available in storage. Also, missing AVI/EXP are checked as well as error messages. These error messages may take on different forms depending on the MP. Many MPs check the so called Maty-warnings to identify problems, whereas others prefer not to and rather investigate the problem themselves in another way. The system Deviation handling, for example, shows if there are any open orders, missing or late goods, and proactive work such as eQuality if often done many times a day. Other tasks include the registration of new parts, checking of parameters in the system and invoices as well as scrapping of parts and introducing new parts is done regularly. A bank holiday routine is also in place to ensure that if there are any days which the supplier, or the Scania PRU itself, is closed, measures are taken to ensure a material flow that does not disturb Scania’s production.

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14 Material Planner 1, personal communication, 2017-02-22
15 Material Planner 2, personal communication, 2017-02-20
16 Material Planner 3, personal communication, 2017-02-21
17 Material Planner 4, personal communication, 2017-02-23
18 Material Planner 5, personal communication, 2017-02-28
Delivery plans are updated and sent to the supplier every day at the Chassi Assembly and Axle and Gearbox Assembly, and on Tuesdays and Thursdays from the Engine Assembly. These plans may be changed up to two days before they are to be picked up, and this time is called Freeze Time. 19

The MPs use information from various sources in their daily work. Some of the functions have been mentioned before, such as Purchasing and Production Planning, but they also contact the Material Handling and Logistics. The communication between these functions is done through different systems. 20

All suppliers need to book transports before noon every day, and after that the MPs check if the bookings are done according to the call-offs that should be sent in the afternoon. There have been incidents where the supplier has forgotten to book a transport, but then a speed transport or an agreement that the goods may be received later can be made. If the supplier is not ready to book a transport in time, the supplier should alert the MP in advance and try to come up with a solution. In the morning, the MPs check if yesterday’s transportations were picked up as planned. All of this is done in Webstars. All deliveries are followed up and the aim is to have a delivery precision of 95%, and this measurement regards both time and quantity. 14 15 16 17 18

Once all the bookings are done in Webstars the Control Tower optimizes the routes and loading of the trucks. This must be done by 15.00 to be able to book all the trucks needed to deliver all the products, this since Scania is responsible for all the deliveries into Scania. To be able to optimize the flow the Control Tower have the possibility to move orders further into the future a few days. One measurement which is used by the Control Tower is OTIF – On Time, In Full – which takes into consideration the call-off made by Scania, the booking of transport by the supplier, all the way delivery of the material to Scania. This differs from the definition of delivery precision made by many MPs since it mainly measures the delivery precision in terms of delivery in the right time and in the right quantity and another measurement is used for the evaluation of booking transport in the right time. 21

At the Engine Assembly the systems Deviation System and QlickView are used, and at the Axle and Gearbox Assembly the systems have recently been implemented. These are two systems that are meant to help the users by giving an overview of information. Deviation System is a list of deviations amongst the arriving goods. Then the MPs, and others affected, can see the status of the incoming good and if it is retrieved or still not in the inventory. The Axle and Gearbox Assembly also uses Deviation System to follow up on articles likely to be on shortage if a delivery does not come soon. QlickView is a system where statistical information of different sort can be visualized. This is to give the users an overview of the information in an easier way. 14 17 18

All deviations that are due to the supplier, and not communicated beforehand, are reported in a system called eQuality. The reports are accumulated per article and then the statistics are used when Purchasing are to do a new purchase or to follow up a current supplier. The type of deviations that are reported by MPs are everything from deviations in quantity to deviations in delivery time. 14

19 Manager Material Control, personal communication, 2017-03-29
20 P&L IT Portfolio Management – Logistic, personal communication, 2017-03-09
21 Head of Supply Chain Development and Supply Chain Developer, personal communication, 2017-03-30
Other systems used by the MPs, but not as often as the others are Efhekt Baseware and AROS. Efhekt Baseware is used for invoice handling and AROS when articles are phased in and out of the product structure. The MPs continuously follow up many parameters to improve the system and make cost savings. These parameters include mean handling time, which effects the supply lead times, number of new and outgoing articles. The stock value in storage and missing AVI/EXP are also controlled as well as if the suppliers are delivering in the right quantity. Since the sequence changes may affect the availability of material in the same way material shortage may cause a sequence change the number of sequence changes is followed upon. How deviations differ from the original plan and the forecast is revised by some MPs themselves. Other parameters include the number of speed transports, cover time, inventory value, top ten suppliers, number of call-offs, and created and closed eQualities.

Some MPs often use the Financial department to follow up on the value of the inventory whereas others prefer to use MS Excel-files such as a local one named “Huvudlistan”, to generate their own analyses regarding for example inventory value and cover time. It may very well be that many MPs could benefit from the usage of an automatic analysis of future capacity needs, as well as future changes in takt time. Having an improved communication about the future states of the production could prove useful for an MP when making call-off and also for the supplier to become more prepared for volume changes. However, there are also indications that other functions would prefer to keep information about volume increases and decreases quiet in order to not reveal too much about Scania to not risk spreading sensitive information.

Knowledge is often transferred between the MPs at the different PRUs. For instance the Axle and Gearbox Assembly often study what has been done at the Engine Assembly. One example of this is the usage of the Deviation System which originates from the Engine Assembly. Sharing information is not common and is often a base for continuous improvement. Other areas that could be improved is for example the communication with Purchasing, which some MPs believe only focus on cost reductions rather than factors such as lead times and quality.

Figure 23 Main information input, output and systems used by the MPs in Södertälje.
4.4.3 Internal Logistics

The internal logistics at Scania are responsible for supplying all PRUs with material and to bring the material to the production line. This is done by first unloading all deliveries at the main storage, which is structured differently at each PRU. The Engine Assembly has its own main storage nearby the Engine Assembly, and the Chassi Assembly and the Axle and Gearbox Assembly share one main storage called Logistics Centre, but also separate storage locations. At the end of this chapter, in Figure 24, a general overview of some of the main input, output and systems used by the Internal Logistics in Södertälje.

From the main storages material is brought to, so called, platforms where material is prepared and put into kits, smaller boxes, and placed on the right types of racks, which are delivered to the production line. The delivery is done with trains that are takted by the production. It takes a train a certain amount of taks to complete its run, and it delivers material that will supply the assembly for that time period. If possible, the whole pallet is delivered to the assembly line, but there are restrictions due to space at the line and the demand for the article. Articles with low demand are not delivered to the line in pallets, for example.

At the Chassi Assembly there are three platforms supplying the assembly line. Depending on where in the assembly an article is needed, it is located at different platforms.

At the platforms an application called Picking is used at some PRUs. It is an application extracting information from Mona to create lists of what needs to be picked on the next train to be delivered to the production line. When picking material it is possible to deduct material earlier by printing out the picking instructions earlier from the system. This has sometimes caused issues with the wrong balances in the systems. However, there are current projects investigating how these early printouts can be avoided.

When suppliers deliver material, it is done in predefined packaging, according to a Scania standard. This is done to avoid the material being handled more than necessary and it can go straight from the inventory to the production line. How the packing should be done, is decided by following a standardized procedure. The main aspects considered when choosing the packaging is the production demand, the quality demands, the size of the part and information from the Plan for Every Part (PFEP), but the whole logistics flow should be considered when choices are made (Lööv, 2015).

Scania always strive towards the smallest packaging possible, however, due to for example weight limitations a larger packaging may be needed. As a general rule a box should last for at least two hours at the line without needing to be refilled. The two hours refilling rate is set in relation to how long it takes to replenish a box at line.

When an order is made, the supplier must fill the bottom of a pallet with boxes. Therefore, Scania strive to fill the bottom of a pallet with boxes, either with different articles or with all of the same kind. However, if this cannot be done empty boxes must be used to fill the pallet. Depending on the demand of the product and the size of the boxes, whole or half pallets are ordered. This in turn affects the order quantity and the stock level.

The material handling is divided into two main parts – Factory Feeding and Line Feeding. The Factory Feeding is responsible for handling the goods from transport, goods reception, storage, as well as parts

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22 Logistic Developer, personal communication, 2017-04-05
23 Packaging Engineer, personal communication, 2017-03-16
of the KD packaging and some delivery directly to the assembly line. Since goods reception is part of the work, a need of knowing when transport will arrive exists and therefore Webstars is sometimes used. (Malki, 2014) The Line Feeding is mainly responsible for delivering material from platforms and storages to the assembly line. For Line Feeding this includes batches of low and high frequent material, sequenced articles and kitting. (Guvå, 2016) The main function of both Factory Feeding and Line Feeding is to, with the input of functions such as logistics, MPs, and PPs, deliver material in the right quantity at the right time with the right quality, which also is followed up on. (Guvå, 2016; Malki, 2014)

![Figure 24 Main information input, output and systems used by Internal Logistics in Södertälje.](image)

### 4.5 Production at Scania, Zwolle

In Zwolle, Scania has a production site for the final assembly of trucks. The site has two truck assembly lines, called Pollux and Castor. The two lines together produce up to 180 trucks per day. In Zwolle there is an ongoing project called Flow Oriented Factory Feeding (FOFF) with the aim to enable the PRUs to cooperate more regarding material planning and call-offs by centralizing the material planning function, having the MPs responsible for suppliers in a region or a specific flow.

The general structure of the main assembly line is similar to the Chassi Assembly in Södertälje. However, instead of having a truck assembly line and a bus assembly line, the production line in Zwolle consists of two assembly lines for trucks. The material supply method to these lines is similar to the one in Södertälje, with for example kitting, batch and sequencing of material. However, due to the U structure of the two lines, with one of the lines inside the other, it is not always possible to have exactly the same supply methods. Since it is only the old truck currently being produced in Zwolle, large preparations are made for the possibility to assemble both the NCG and the old truck as the same time, a preparation which requires not only time but also a study of the supply methods and the inventory space available.²⁴ ²⁵

#### 4.5.1 Production Planning

The PPs in Zwolle have the responsibility for planning different areas of the production. One is responsible for the mixing and planning of production, one for KD trucks, one for the production in Meppel and reports from there. The team leader for the PPs handles the contact with the CPP and other PRUs. The main information input and output used by the PPs in Zwolle, together with the systems used, is shown in Figure 25 at the end of this chapter.²⁶

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²⁴ Logistics Engineer, personal communication, 2017-04-21
²⁵ Group Leader Production Planning, personal communication, 2017-04-20
²⁶ Group Leader Production Planning, Logistics Analyst, and Production Planner 5, personal communication, 2017-04-20
Once a week the CPP allocates about five days of production to the PRU four weeks in advance. There are rules the CPP must follow which means that they cannot allocate more than a certain number of trucks of one type, due to restrictions in the production layout. One example this is the number of multi-coloured cabs. Once the CPP has allocated what trucks to assemble in Zwolle and all the rules are followed, Status 1 is achieved and the PP may start mixing.  

The mixing is done in accordance to mixing rules in PRAL. The mixing is done for the two lines and a sequence is established for the production. With the mixing done and approved it becomes a Status 2 and can be sent to SPARTA, which breaks down all the material needs in MA.  

The PPs are also responsible for the components, such as engine, axle- and gearbox, and cab, to arrive in time for production. There is a rule saying that the assembly of a truck may not start unless all components are in store to ensure that there is no missing material. Therefore, the PPs also check the supplier capacity of material with the MPs to ensure all materials are in place as well as handles the SFA, to ensure the capacity is enough to cover the production to be done.  

Apart from contact with the CPP, MP, and other PRUs the PP have contact with the engineers for material handling and production to know what is going on and what needs to be done.  

Other systems than SPARTA and PRAL, used by the PPs are Webstars, to trace component shipments, MA, IACOB, and Physics. Physics is a system used for tracking the cabs, and when assembled, the truck using RFID tags. The tag is placed in the cab window in Oskarshamn where it is produced and then it is scanned when the cab is tested and at the line to know where it is located on the line.  

The production planning is followed up on number of non-direct runs, meaning number of trucks that are not complete after the end of the line and needs to go through complementary actions. The number of sequence changes and re-schedules done are also followed up along with the reason for why these occurred. Other things that are followed up are delivery precision of material and components, material quality, and when the production is late to a Customer Release Date.  

Among the production planning there is a wish to know more regarding the upcoming needs and customer demand to be able to plan and prepare in advance. There is also a wish to know more about the progress on the line and to be able to follow it more closely. This to know what is going on and if it is late or if changes of some sort are needed.  

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![Diagram](image)

*Figure 25 Main information input, output and systems used by the PPs in Zwolle.*
4.5.2 Material Planning

Being an MP in Zwolle could currently mean two things – an MP as found at other PRUs or an MP as part of the FOFF-project. The main information input and output used by the MPs in Zwolle, together with the systems used, is shown in Figure 26 at the end of this chapter. The FOFF project is explained in a separate part of this chapter, however without a figure. 27

As in the case with the MP at Södertälje the role of an MP is to be responsible of ensuring the right material at the right time for the production. There are a set of tasks that have to be done daily set as a standard. These tasks include the checking of Maty warnings and error messages, contacting suppliers if they are late, and follow-up of the work. Part of the responsibility is to continuously be responsible for parameters related to the material call-offs at Scania such as packaging and unit quantity, both of which are followed up upon and coordinated by a production engineer. Also, the Safety Stock in Days (SSD) and the safety stock in hours is studied. The bank holiday routine is continuously revised since the call-offs have to be done manually if there are deviations to the pre-made plan generated by the systems. A logistic analyst in the team is the main responsible for the setting of parameters. 27

The various systems used include the Mona systems such as MA, MC, Mona Material (MM), Scania International Material Administration System (SIMAS). Other systems are QlickView, used for allowing an overview of the suppliers for example, AROS for spare parts, Exemption from Requirements, and special orders. Furthermore an internal Deviation System in the shape of an MS Excel-file is used to follow up and logging all deviations that may occur. For the booking of transports Webstars is used, Scania Outgoing Transport and Invoice handling (SOTig) and Efhekt Baseware for invoices and eQuality for quality issues. Further, Prossess is used for all chassi assembly workshops to follow up the quality and the after line processes. For an MP the Prossess system is mainly used to study what material is missing in the production and adapt the material to this. The vast amount of systems needed in the daily work are sometimes considered complicated in the sense that many things need to be double checked and a suggestion would be to generate warnings more adapted to a dashboard. The majority of the systems are used in the same way as the systems at Södertälje, with some configuration changes such as not having access to Huvudlistan. 27

Pulse meetings are used to follow up the work of the MPs daily. Parameters that are followed up upon include the number of non-direct runs caused by MP, postponed chassis and the delivery precision. The number of scrapped parts is also studied and the value of these together with the scrapping strategies to find possible ways to become more efficient and make savings. As in the case with Södertälje the delivery precision is defined as deviations in both time and quantity. 27

Functions which often are in contact with the MPs include product and process engineering, external and internal logistics, and purchasing. 27

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27 Team Leader Material Planning and Material Planner 6, personal communication, 2017-04-20
Flow Oriented Factory Feeding

FOFF is a one year project started in August 2016. The initiative behind the project is based on the material handling at Scania, a previous project which resulted in more focus on stock and transportation costs, and a larger focus on logistics centres. It is believed that the project will generate a more global logistic network with flexible material flows together with stock optimization and a better use of resources. At the same time transport efficiency is believed to be improved. One example of a direct application is that there should be a possibility of sending material between different PRUs, for example between Zwolle and Anger it is only eight hours transportation time. Such a distance allows for sharing material.  

Currently there are many MPs connected to one single supplier. This means that if there is a possible delay in delivery which concerns several PRUs, several MPs will be in contact with the supplier and the MP that screams the highest that will get the delivery. For low consumption parts the call-offs varies with different PRUs, which means the supplier may receive volatile forecasts and call-offs. Centralizing the material planning could help distribute material and also deliver a more stable forecast and plan to suppliers with only one contact at Scania. Today there exists some coordination between the various PRUs and material is sent back and forth in order for the production to continue, but the FOFF project emphasizes that the coordination could be greater. 

Another point of interest is the limited space that each PRU has available for material and inventory. This will, in correlation with possible options of sourcing from new locations, generate a greater need of inventory management and control. The batch sizes are another area of interest and possible cost savings are believed to be found if low volume products could be organized better and shared between different units. This is also the case for other products. One example is if a product has a batch size of five units in a pallet, and the demand at three different PRUs is six, nine, and ten respectively. If the demand was aggregated and put together for the three PRUs only 25 units are needed and a call-off for five units is enough to cover the need. But if the call-offs are not done in a coordinated way the demand would be two separate orders from each PRU to cover the needs. This means thirty units will

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28 Project Leader FOFF, personal communication, 2017-04-20
be ordered in total, but five would go to waste since the PRUs are not sharing products between each other.  

The role of an MP working with FOFF does not change much in theory compared to the other MPs, even so, there are some differences. Rather than being responsible for a specific supplier a FOFF MP is responsible for a specific flow of material, one example being the North Bound Flow, with a contact person at each PRU. Since each PRU is using its own database for MC the work today of an MP is quite time consuming looking through different systems. However, if FOFF is to be continued an integration of the different PRU systems will be done. Depending on which PRU handling the tasks, different focus is set on different things. Some MPs do not use the Maty warnings, whereas some rely heavily on the Maty warnings in their daily work.  

The systems used by the MPs do not vary much compared to other MPs. MC, SIMAS, Webstars, QlickView, and eQuality are used on a daily basis. Other systems used include TRAIL which is a system used to track and trace material to and from Brazil, and iFOT which used by to optimize the transport network. Optimizing the transport network is sometimes hard since information often is received from the supplier regarding the status of the transport rather than the transport itself. Having information of where the transport is located and when the material is expected to be delivered would help the MPs in their work since both the external and the internal logistics could be coordinated better.  

Parameters that are mainly studied are Material Handling Time (MHT), SSD, and Safety Stock in Quantity (SSQ), together with buffers, transport times, and pick up dates. Following up the work is often done by studying the delivery performance, which consists of the right delivery time and the right quantity. The number of parameters that need to be controlled would perhaps be decreased with FOFF since the parameters will be aggregated for all the PRUs. However, other tasks will be added. For instance, the transport optimization will be added as a task, something which is currently done by the Control Tower in Södertälje.  

4.5.3 Internal Logistics

The internal logistics in Zwolle are divided into Factory feeding and Line feeding. The Factory feeding handles all incoming goods and place them in storage. Line feeding is responsible for all the picking and kitting of material, but also for delivering the material to the line. The main information input and output used by Internal Logistics in Zwolle, together with the systems used, is shown in Figure 27 at the end of this chapter.  

When goods arrive at the gate the Goods Administration checks what is loaded on the truck with SIMAS and ensures that it is correct. If not, they need to figure out if there is an error in the system or if there is something that is not correct with the incoming goods. When everything is checked the goods are placed in the right storage. Components are stored in the trailers in a parking lot and gathered when needed. Other goods is either stored in the Manual Storage or in the Picking Storage. All goods that is to be delivered to the line in a pallet are brought to the manual storage and from here Factory feeding delivers the pallets to the line when needed.  

Apart from handling all incoming goods, Factory feeding also has the responsibility for all incoming components and that they all are delivered to the line at the right time.  

29 Material Planner FOFF, personal communication, 2017-04-21
30 Workshop Manager Factory Feeding, personal communication, 2017-04-21
When the incoming goods are late and there are an urgency to get it into storage or to the line the delivery can be marked Prio 1 or Prio 2. Prio 1 means that once the delivery comes to the production site it is unloaded at once and the goods is delivered to the line. All the administration is done after the goods is transported to the line to speed up the process. Prio 2 means that the incoming delivery skips all the waiting lines and the administration, unloading and storing is done straight away.

Other than using SIMAS when goods are arriving Webstars is used to know what goods will arrive when. To report transports that do not live up to the agreements eCarrier is used. It is a system similar to eQuality but for transports. If the delivery precision deviates from the agreement in some way this is reported to the MPs.

The parameters that are followed up upon is stop time at the line, non-direct runs, and touches that is caused by the Line and Factory feeding. Touches are errors that were able to be corrected along the line, and non-direct runs are errors that are corrected after the end of line.

To be able to know how much personnel and to plan the storage space properly, it is important for the Factory feeding to know how many pallets that are coming in each day. At the moment, they check the planned arrivals two weeks, one week, and one day ahead and then compare this to the real number of arrivals. This is done in order to follow up on the planning.

Line feeding is responsible for all material that needs to be reorganized before going into line. All the picking, kitting, and loading of racks is done from pallets in the Picking Storage and then sent out to the line on trains. The trains leave at certain times to match the takt time and supply material when needed. Within production there is one person responsible for scanning all empty bins in different zones, triggering the order of material to the line.

![Figure 27 Main information input, output and systems used by Internal Logistics in Zwolle.](image-url)
4.6 Production Systems at Scania

At Scania, there are multiple systems used within the production that supply information of different sorts. The systems are connected to one another as summarized in Figure 28 below.  

![Figure 28 How order information travels through the systems and how it is spread.](image)

First the IACOB system aggregates the customer orders, generating an order book. Then SPARTA, focuses on handling the internal production order allocated to different PRUs. SPARTA is used by the CPP to allocate the customer orders to all PRUs. The PRUs mainly uses the Mona systems, consisting of Mona Assembly (MA), MM, MC, and SIMAS.  

MA is used for planning, preparation, and production, MC for delivery plans and deliveries from suppliers, MM for valuing the production, and SIMAS for handling the inventories. These four modules share information amongst each other and MC also gets information from the AGDA system, which creates plans for call-offs and deliveries from the suppliers. AGDA works with Gross Demand Calculations based on Firm and Open orders, but also statistics. The volume planning is processed by Gross Demand Forecast Calculations and later used by MC and Purchasing. (Jamshidi, 2017)

Apart from the earlier mentioned systems Scania IT also supplies the production with other systems. The Mona systems constitutes the ERP system and part of the MES at Scania and the SCADA system is called DIDRIK.  

A third system that is relatively new is the EBBA system which will become the new MES, however, it is only carried out at the Axle- and Gearbox Assembly and at parts of the factory in Oskarshamn. An overview of how the systems are connected can be seen in Figure 29 on the next page (Rosengren, 2014).

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31 System Analyst for MC and MM, personal communication, 2017-03-01
32 Lead Architect Order to Delivery, personal communication, 2017-03-28
33 Project Manager Logistics, personal communication, 2017-03-29
4.6.1 Mona Systems

The MONA systems are the main systems used within the production and include multiple modules with the aim to support the local production and the staff working in connection with the production. It consists of different modules, used by various people for various purposes described below. (Dalvik, 2016)

MA is used for deciding when the products will be produced and at which PRU. Each product has a scheduled end, which is when it is planned to go out from the final assembly line. This time dictates when all other components needs to be done, together with lead times and buffer times. The sequence is frozen a certain number of days before demand time, which is when the material is needed at the assembly line. The information from MA is the base for both MM and MC. 31

In MC a comparison is done between the incoming orders, from MA and ADGA, with the latest storage update in SIMAS and from that an order is generated to the supplier if needed. SIMAS also supplies MC with information regarding the availability in stock. However, the available material withdrawn to the assembly line is not shown in the system. 31 In MC the MPs can decide the value of certain parameters. The parameters are SSD, SSQ, and MHT. These parameters along with Transport Lead Time (TLT), buffer times, and what days there is a pick up at the supplier decides when material should be ordered. How all of this is calculated within MC is shown in Figure 30 below. 19
The main tool used by the MPs is MC and each MP is responsible for the procurement of a certain type of products and suppliers. In MC the current inventory level is shown and when automated call-offs will occur. MC is updated once each night with the current stock levels. Almost all call-offs are done automatically, but some articles are put on manual delivery plans, which means that a call-off must be done actively by the MP. From MC an updated forecast for upcoming deliveries are sent to the suppliers every week and if anything deviates from the planned outcome MC alerts the MP and measures can be taken to solve the problem.

In SIMAS the inventory is updated during the day. Here the MPs can get information about the addresses at line where the products will be needed as well as goods that has not been checked in after a delivery, as it should have been.

As for the role of the MP some of the most important information is the material need. For this, the process can be divided into separate call-offs – Batch and Sequence. For material, which is handled in a Batch call-off, the order is sent continuously sent out to the supplier, different input is used to calculate the material requirement, as can be seen in Figure 31 below.

The Internal Long Term Requirements are based on a forecast reaching 12 months into the future and is continuously updated. The forecast is done in AGDA and the fixed requirement, consisting of four weeks, is done in MA and transferred to MC. The Long Term forecast is then aggregated and the forecast is updated once a week. This work is done mostly automatically, and it is often the suppliers who react if the forecast change drastically. If this is the case, the MPs are informed.

Closely connected to the Long Term is the material requirement for the Short Term. When an order is broken down in MA the requirements of articles and components are fixed for the upcoming four weeks. The system automatically calculates when the next call-off needs to be made, depending on the available inventory and the takt in the production.

The material requirements based on Historical Consumption is mainly for articles that are considered impossible to make a forecast for, for example if the requirements vary from time to time. In cases like these, the average historical consumption is used. Since these components are low in volume, the inventory space that they take is negligible.

The input from the Order Point is mainly used for articles using a Reorder Point System, however, the MPs mainly use the Batch System. Manually Added Material Requirements refers to extra orders which are not included in the forecast, such as orders from Preparation. Material Requirements from Other
Customers are for example requirements from Spare Parts, a function governed by a function called After-Market.  

The components and articles using the sequenced call-offs are connected to a customer order using an EDI standard. The reason for having a sequenced call-off for an article is usually that the article is bulky. There are three main times that are of importance to the sequenced call-offs. The first one is Scheduled End which indicate when a supplier receives the information regarding the call-off. Another type of information is the Frozen Specification which indicates what type of product that is needed. The last type is the Frozen Sequence which states when the component will be assembled. These three times make up an Assembly Order to a PRU, which is sent as a Sequence Call-Off, visualized in Figure 32 below. It is not uncommon to place sequenced call-offs every day and in general the buffer time is eight hours before the component is assembled.  

The information in SIMAS is updated as soon as something is picked out from stock, however, where that point is may differ from PRU to PRU. In SIMAS there are two types of balances, Store Balance and Workshop Balance, and a configuration decides what material belongs to which balance. All main storages belong to the Store Balance, but when it is brought out of storage the differences begin. In Figure 33, on the next page, different configurations are visualized, but more SIMAS configurations exist. The different Store Balances are related to SIMAS and the possible configurations that can be made. The PRUs have decided to count material in different ways, and therefore it is deducted differently. However, all material is deducted in whole pallets, or boxes, and once it is out on line it does not exist in the system.  

MM values the production and the inventory by calculating the current value of the WIP and the current stock level.  

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34 Logistics Development, personal communication, 2017-04-03
4.6.2 EBBA
The EBBA system, a MES system, is a quite new system and has not been implemented at all PRUs. It has been implemented at the Axle and Gearbox Assembly and at parts of the factory in Oskarshamn. So far it has the functionality to keep track of the production sequence and when all operations are to be performed, and thereby a calculation of when material is needed and when it should be ordered to line. This leads to more precise material deliveries and less material at line.

The EBBA system derives data from the EBBA-DIDRIK interface and more functionality that is to be included is to use the derived data in regards to Overall Equipment Effectiveness, KPIs, traceability, deviation handling, local planning, and supply and inventory control, as well as electronic work orders. (Scania Wiki, 2013a) Other areas which can be offered are Statistical Process Control, local sequence management, material handling, and maintenance. (Rindeström, 2017) EBBA then offers an interface towards MONA (Scania Wiki, 2013a).

4.6.3 DIDRIK
The SCADA system at Scania is called DIDRIK and focuses on connecting production equipment for traceability, takting, and production follow-up. DIDRIK was originally created to support functions such as tracking, takting, traceability, paper-less assembly, and support for KPIs, as well as scheduling. (Scania Wiki, 2013b) Today it is where much of the production logic is. It has information regarding all the stations at the line and it controls and supervises all the processes and operations.

The main purpose of the system is to ensure the quality of the processes and to be able to trace quality problems to a specific time in production. Thereby, if an error is detected among the trucks they can trace exactly which trucks that needs to go through a quality check. DIDRIK is also used to visualize the status of the machines within production and display this to the operators. It can also be used to log how many hours a machine is used to know more precisely when maintenance will be needed.

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Manager – Automation, personal communication, 2017-03-22
4.7 Information Management Journey

The CEO of Scania has stated that all data gathered at Scania should be available for everyone at Scania and a project called Information Management Journey (IMJ) has been rolled out since then. The aim of the project is to collect information about how for example processes, machines, and trucks are conducted and used today to be able to create new services and business concepts for the clients of Scania, but also for the workers at Scania. The information that is to be collected comes from Legacy Systems, Scania Managed Devices, and external sources. The Legacy Systems are the systems that exist to support someone within the company, the Scania Managed Devices consists of all devices that can be connected, such as a robot cell that send information to a server. The external sources consist of all information sources outside of Scania. By collecting all this information, the needs of the customers and the customers of the customers may be identified in an easier way, but also help the operations within the organisation. There are three types of analyses that can be done; BI analyses, Self Service, and Big Data Science. The BI analyses are the classic type of BI where measurements are shown on a dashboard and reports are published. Self Service means that everyone has access to information and can show and handle it as they like to make use out of it. Big Data Science is the type of analysis that is done on a large amount of data to find new correlations and there is a possibility to fins new knowledge within the data.

To realize the project, four different aspects need to be defined for the project to be successful throughout the company. The four aspects are Availability, Quality, Capitalisation, and Mind Set. As a complement to these four aspects, a rule has been established all through Scania that says that all information should be available for everyone to make the process of IMJ easier and to fulfil the vision established by Henrik Henriksson.

The implementation of the Data Lake, where all the information will be collected, have started on a small scale. Copies of some sources have added to the lake and the structure of the data in the lake is the same as in the original system to simplify the implementation and make use of the data as soon as possible. The only criteria on the data that is put into the lake is that all data in a system goes in or nothing at all, and that it must be valuable for a larger number of people within the organisation.

4.8 Plan for Every Part at Scania

A PFEP is a lean tool which is a document containing data about all the products and articles used at a plant. The information should be detailed enough for each plant to enable effective, lean material planning and usage. PFEP is a flexible, living document that needs to be updated as times goes and products and articles are updated. (Harris, Harris, & Wilson, 2003)

The creation of a complete PFEP can be extensive and take up to a few years if a large number of articles are used within the production. The PFEP itself is only the information recorded in a document or database, but it can help the material planning and rules can be established for every part used. (Bartholomew, 2015)

During the last few years a group of people at Scania have been working on a project called PFEP with the focus to develop the logistic activities at the company regarding storage, packaging, and transportation. The goal is to collect, organize, and maintain a database with all the information needed in the logistic activities, so that the personnel do not need to look for information in multiple locations. The same information should be available to all production units and the system should recognize variations in data and warn if something should be changed in the system. As of now the
A working group at Scania has identified what information should be collected in a global database available for the logistic personnel and are waiting for Scania IT to implement the tool to be used.  

In the pilot project, with the focus on the packaging technicians at the engine assembly, it has been estimated that 6,000,000 SEK could be saved by continuously revising the information regarding the articles. Example of information that the PFEP contains is batch sizes, name of suppliers, transportation distances, cover times, and consumption volumes.  

PFEP aims to facilitate the access of information and also as a mind-set as to how easy it is to improve the parameters set today. Furthermore, since the idea is to have a global database it is possible to also compare one PRU to others and perhaps increase the transparency between different PRUs. In the long run, the system could become more proactive and signal how future states would affect the material flow. For example, if the takt time is changed, a reaction as to whether the batch sizes could change as well as a result of this takt change.  

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36 Logistics Development and Consulting, personal communication, 2017-02-08  
37 Logistics Development and Consulting, personal communication, 2017-04-26
5 Findings in the Market

As part of the study another actor within Smart Manufacturing was investigated and used as a comparison to Scania and their operations. Virtual Manufacturing AB was interviewed to get a deeper understanding for how digitalization of production can be useful for a company but also to broaden the perspective of how the material flow can be managed.

5.1 Virtual Manufacturing AB

Virtual Manufacturing AB (Virtual) was founded in 2006 and has its headquarters in Gothenburg, Sweden. The company has offices in Linköping, Köping, and Oskarshamn in Sweden, and Aarhus in Denmark. (Virtual Manufacturing AB, 2017) The main reason for being located in Oskarshamn is the Scania production site for cabs. Virtual offers products and services within product and production development to its customers and their goal is to help manufacturing companies to become leading within their industry. (Virtual Manufacturing AB, 2017)

Having been in the business for quite some time, with around ten years of working with digital manufacturing, Virtual offers many services connected to Smart Manufacturing and Industrie 4.0. According to the company, Digital Manufacturing is comprised of three main areas; Smart Analytic Systems, Real Time Communication and Visualization, and Physical Web for Manufacturing, as can be seen in Figure 34 below.³⁸

![](image)

**Figure 34 The three main components of Digital Manufacturing according to Virtual.³⁸**

_Smart Analytic Systems_ refers to the collection of data that is to be related to the performance KPI’s of a factory. These data and KPI’s will then be simulated and optimized through various tests. If the results prove useful to increase the efficiency of the factory the simulated changes are implemented in the real world. The second area, _Real Time Communication and Visualization_, offers a base for daily management, real time reactions and analyses. The _Physical Web for Manufacturing_ offers a possibility to trace material to a greater extent. The system was originally created by Google, but it has been developed further and with the use of beacons it is possible for connected objects to interact with each other.³⁸

Examples of information input which is important when working with Digital Factories include the actual takt time, location of data collection, type of material, as well as packaging. Other input that may prove valuable includes the routing of material, decisions rules, working schedules, order handling, mean time between failures, mean time to repair, as well as other processing times. Results that Virtual have seen so far include improvements in delivery precision, buffer sizes, lead times and utilization rates.³⁸

Where to draw the line for where to stop collecting data is hard to make. It is important to collect enough information to make adequate decisions and therefore, it is not only important to have both enough data as well as the correct data. Virtual divides the decision process into three stages with the first one being simply having the data collected. The second stage is to retrieve the relevant

³⁸ Virtual Manufacturing, personal communication, 2017-04-11
information followed by the last stage which include the usage of the data. The possibility to trace the information allows for a greater understanding of processes and material flows. For example, the way KPI’s are used may very well change in the future since the KPI can be connected to the process, batch or even individual if needed. However, there are questions as to what extent individuals should be allowed to be followed up upon.

Methods for handling material and processes can be changed when working with an increased usage of IT in the production. Examples include pick to light, pick to voice, and also eyewear which all help the picker to retrieve the correct material and also help the system being updated with the correct inventory levels.

One thing that is important when working with Digital Factories and simulations is that the digital copy of the factory should be considered a twin to the physical production. In other words, if a change is made in the Physical factory, a change should also be made in the Digital one. Also, it is possible to work with continuous improvements in both factories. One example is Volvo Lastvagnar AB (Volvo) in Umeå which has a simulation of the production flow that is run six hours in advance to the actual, physical, production line. This allows for the factory to receive warnings before the production even has started. Of course, as always, there are some breakdowns that are hard to foresee, but in general surprise avoidance is possible. The use of Discrete Event Simulation can also result in changes in production plans and reducing lead times, identification of bottlenecks and tests of investments.
6 Analysis

This study was composed of three analyses of which the first, based on the literature review, focuses on finding areas of information, that is of interest for the material flow. The second analysis was then based on these areas and applied at Scania. The last and third analysis takes on the Industrie 4.0 approach and focuses on what is needed in order for a company to become smart. All in all, these analyses compose the base of the recommendations then formulated for Scania and Scania IT.

6.1 Identification of Information Needed when Planning Material Flows

When studying the different aspects of planning and how it should be organized according to different authors, it can be stated that the planning structure depends on the stand point of the author. Where within an organization the material planning should be placed is thereby discussable, and this is due to the material flow being involved in the whole planning process and regards multiple functions. (Jonsson & Mattsson, 2003; Segerstedt, 2008)

Even if the placement of the function material planning may vary, the information needed and execution is quite similar. Jonsson and Mattsson (2003) have a list of steps when planning production. It starts with creating a forecast of the upcoming demand, then creating a preliminary delivery schedule, and based on the delivery schedule and current inventory create a production plan. Segerstedt (2008) has a similar list which focuses the tasks to be performed by an MP. This list includes creating a delivery schedule and manage the inventory levels based on a production schedule. Even though the two lists have different stand points, both point out the importance of knowing what is to be done as well as maintaining the inventory regularly. Therefore, if the base for the material planning process is the production plan, the material needed will be more accurate, however, the planning horizon for the MP will be shorter. If the production plan is based on the delivery schedule, the planning horizon for the MP will be longer, since the forecast is more likely to be for a longer period of time, but there will be more uncertainty in the demand.

In connection to forecasts and uncertainties Anupindi, et al. (2014) mention aspects that are important to consider when planning according to a forecast and one of them is that forecasts usually are wrong. This is central to have in mind when choosing a setup for how the planning should be done within an organization. Other aspects to consider is that aggregated forecasts are more accurate than disaggregated forecasts, and that long-range forecasts are less accurate than short-range forecasts. Therefore, the setup of how the forecast is done can lead to different results, even with the same data available, especially if an objective and subjective forecast is compared. (Anupindi, et al., 2014) Even if a forecast is secured, there are many other aspects that need to be taken into consideration when designing the material flow. Therefore, it is important to have knowledge of the consistency of production process, particularly since there often is a time delay in the generation of data and the use of it (Mattsson, 2012).

The four planning methods covered in the Frame of Reference; Reorder Point System, Base Stock System, Cover-Time Reviewing, and MRP, all have similarities regarding what information is needed when planning production and material. This information includes information regarding the inventory level, the production plan, and a forecast or historical consumption. (Jonsson & Mattsson, 2003) These enable the MPs and other users to know what is missing in the inventory and can place the right number of orders, with the right quantity. However, the planning methods work differently with regards to uncertainties, how orders should be dimensioned, and when orders should be placed. Both
Base Stock System and Reorder Point System focus on the inventory level, however the former system ensures a maximum inventory level, and the latter places an order of a predefined quantity when the inventory is below a certain level. Another point of interest is how the calculations are done within each method. Depending on the set-up of a system, it is possible to work proactively, since changes in order quantities can be done to better match the production demand. A summary of the input that the planning methods work with can be seen in Figure 35 below, which displays all the possible input according to the planning methods described in 3.3 Material Planning. (Jonsson & Mattsson, 2003)

According to the various ordering methods and process flow techniques cited it is important to take various aspects of the production into account when planning lot sizes. Part of the process flow are the COPs and DPs. Jonsson and Mattsson (2003) state that the material that is ordered after the COP in the product structure needs to be acquired after a customer order has been placed. This can be used as an argument for planning the material after the production plan has been fixed, since customer specific material should preferably be ordered once a customer order has been placed. It also increases the certainty of the plan when ordering material connected to a customer order and extra inventory can be decreased, since the SS usually is dimensioned according to uncertainties in both demand and delivery lead time (Oskarsson, et al., 2013).
The main ordering and process flow techniques in this study are the Wilson formula, which focuses on ordering costs, demand, and inventory cost (Oskarsson, et al., 2013), Silver & Meal, that considers the demand, inventory costs, and ordering costs, and Wagner & Whitin, also studying demand, costs, and inventory (Anupindi, et al., 2014). Furthermore, in order to be able to make the correct calculations lead times need to be taken into account as well. A summary of the important input information, besides lead time, can be seen in Table 2 below. Correlating these to the above mentioned planning methods, it can be seen that the material need, costs, lead times, and inventory are of importance when ordering and working with material flows for each production period.

**Table 2 Summary of the important information found in relation to the Wilson Formula, Silver & Meal, and Wagner & Whitin (Oskarsson, et al., 2013; Jonsson & Mattsson, 2003; Wagner & Whitin, 2004).**

<table>
<thead>
<tr>
<th>Wilson Formula</th>
<th>Silver &amp; Meal</th>
<th>Wagner &amp; Whitin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>Demand</td>
<td>Demand</td>
</tr>
<tr>
<td>Inventory Interest</td>
<td>Inventory Value</td>
<td>Inventory Interest</td>
</tr>
<tr>
<td>Order Cost</td>
<td>Order Cost</td>
<td>Order Cost</td>
</tr>
<tr>
<td>Product Value</td>
<td>Product Value</td>
<td>Product Value</td>
</tr>
<tr>
<td>Order Quantity</td>
<td>Order Quantity</td>
<td>Order Quantity</td>
</tr>
</tbody>
</table>

The internal supply methods studied; the two bin system, Kanban, kitting, and sequencing, further emphasize the importance of taking the aspect of capacity into account. Kanban recognizes the need of having knowledge of SS, which also is of importance in accordance to Cover-Time Reviewing. Apart from the inventory being affected by the SS, other aspects need to be considered as well, to know what the inventory consists of and how uncertainties are caused by a chosen supply method. (Mattsson, 2012) The staging of material is part of the configuration of the system and whether the staging is done in the system or physically will affect the available inventory (Jonsson & Mattsson, 2003).

There is no standard for information quality and what should be included when information is shared (Grudzién & Hamrol, 2016). According to Eppler (2006) this means that the information can be of different quality to different people, since information can be both objective and subjective. Overall when planning production and material, it is important to know about future states and what is available now. Even so, being sure of the given information is perhaps more important than having information about events far in the future. Forecasts are a common tool for predicting future states. It should, however, be taken into account that the reality will differ from the forecasted events. Mattson (2012) states that having updated information that is time-relevant, but also reliable is important for the correctness of information. Thereby it can be stated that information spread throughout the company, such as a forecast, must be of the right quality, validity, and correct. (Mattsson, 2012)

Updating the available information is closely related to how the processes within a company are conducted and how the progress of the functions is followed up. Bergman and Klefsjö (2010) state that a common way to measure the quality of goods or services is to consider the amount of quality issues that has arisen. Both the delivery accuracy and the delivery reliability are ways to evaluate the performance of deliveries, both internally and externally. (Jonsson & Mattsson, 2003). To keep the inventory information updated, revision of the inventory levels should also be done continuously according to both Anupindi, et al. (2014) and Segerstedt (2008). Evaluation of the forecasts can be done in a similar way, by comparing the deviations from the forecasted plan with the originally forecasted plan (Anupindi, et al., 2014).
As can be seen in Figure 9 (page 18) of the functions using information available in production databases at a manufacturing company, various sets of information are used by multiple functions. If the users of the data reconfigures it freely, without acknowledging other parties, there is a risk the information used within production is faulty. Therefore, the data and information available should be as standardized as possible to ensure a secure production. The information needs to be trusted by the users according to Mattsson (2012) it also needs to be interpreted in the same way by everyone.

Overall there are multiple factors that must be taken into account when working with material flows. But if some aspects should be highlighted extra it is perhaps the information that has a direct impact on the material flow. Figure 36 below displays some of the most common and recurring aspects to take into account when working with material flows according to the literature review, other than having knowledge about the used planning methods, possible uncertainties, and weaknesses of the organisation. As a complement to the information identified as important above, the production capacity and product structure also needs to be considered and the chosen planning method needs to be reviewed continuously.

Figure 36 The information identified as having a major importance for planning orders, both externally and internally.

6.2 Comparison of Information used at Scania and Identified Information

As mentioned in the previous analysis, the quality of information plays a vital role in the system set-up and the information is active at many levels, for instance in forecasting, inventory levels, and production status, and lead times. At the same time as there are requirements set on the quality of information, the information needs to be shared. When exchanging information there are two important aspects to keep in mind, the willingness and the connectivity according to Fawcett, et al. (2007). By having different databases for each PRU at Scania the connectivity is lessened, even if the willingness is high. In general, the willingness to share information within Scania can be considered moderate. When information is asked for, it is shared, but sometimes needed information is not shared, due to the sender not being aware of that the receiver needs it, or simply because the sender does not want the information to be shared.

By sharing all information in, for example, the Scania Data Lake created in the IMJ project, the connectivity within Scania would increase. Even if this in theory also would increase the willingness to share information, it is important to explain why there are advantages to sharing information, which includes for example possible correlations in information to be made. Further, this aspect will enable trusting relationships within the organisation according to Fawcett, et al. (2007).
The different functions at Scania require different information about the material flow to be able to do as good of a job as possible, based on the requirements set upon each function. One aspect to keep in mind is that all functions need to strive towards the same goal, even if they are working with different things.

The following sub-chapters focus on the areas found as important in the previous analysis for the planning of orders.

6.2.1 Historical Consumption, Forecast, and Production Plan

At Scania the forecasted customer orders are updated frequently to always cover the upcoming 12 months. This means that the certainty increases as the months come closer in time, which also is confirmed by Anupindi, et al. (2014). The CPP at Scania creates a plan from the received orders, allocating them to each PRU. The plan created for the production at the different PRUs is based on the incoming orders and mixing rules, and this then dictates what material is needed. Jonsson and Mattsson (2003) states that the COP is the mark of when the production is done according to order and at Scania all assemblies are done to order. The detailed assembly plan at Scania is therefore not done according to a forecast, due to the fact that the COP is located before the assembly starts. This means that if the delivery lead time, SSD, and MHT together are shorter than the fixed planning horizon, the planned part periods, all call-offs are made after the COP and are based on real facts in accordance with what is stated by Jonsson and Mattsson (2003) regarding COP. The material demand for the upcoming weeks is determined and thereby the MPs can place call-offs for specific products. However, this is only possible if the parameters in MC are revised continuously.

If there is an issue with the material supply at Scania, the production plan is adjusted according to material availability. The idea is that by planning material according to the production plan created, the material must be able to arrive within the planning horizon of the detailed plan, otherwise the call-offs will need to be made according to the forecast. If the call-offs are able to be done according to the detailed plan based on customer orders, they can be done when material is actually needed and not when they might be needed. Still, this would lead to material being ordered based on a forecast and a larger inventory due to uncertainties in the demand, according to Oskarsson, et al. (2013).

On a general level, as explained by Figure 31 (page 55) and Figure 32 (page 56) describing the information connected to material requirement for Batch and Sequence call-offs, much of the basic information needed for material demand and calculations is already available in the systems at Scania. However, there might be a gap in the understanding of the users as to how the calculations are done which inhibit the full usage of the systems on a regular basis.

Even if the basic information for generating a call-off in terms of historical consumption, forecasts, and production plans are fulfilled, there are some gaps in the information. For instance, the information given in the forecast could be more detailed and orders could be allocated earlier. Some PPs at Scania would for instance like to know more about upcoming orders further in advance and if there are campaigns on certain models. In theory it would be possible to receive more information within a forecast, but perhaps much information is filtered out before the capacity is calculated by the CPP. Furthermore, if there are many incoming orders there might be a possibility to release plans from the CPP earlier, allowing for more flexibility within the production plan. If orders would be allocated earlier the whole supply chain could benefit from it. The MPs would be able to send more trustworthy delivery plans to the suppliers, the PP would be able to plan the capacity needed earlier, and the Control Tower
would be able to optimize call-offs. Once again it is therefore important to have information that is correct, as well as with time-relevant and complete. (Mattsson, 2012) The assertiveness of the forecast could further be improved if it is revised continuously. Indications have been seen that following up on forecasts and expected production levels is not always done. For instance, when the consumption of certain articles increases the Purchasing department are interested to know this beforehand to be able to negotiate this with the supplier.

An outline of some of the identified information matching the identified input in literature can be seen below in Figure 37. Noteworthy is that the input also includes order point, which can be connected to lead times, and product structures.

Figure 37 A matching of the input available at Scania with the identified information found in the literature review using the Batch and Sequence Call-Offs and the production plan.

A common picture for the whole of Scania, as in Figure 37 above, is hard to make since the transparency of information is not always very clear. For instance, since every PRU makes a call-off based on their own specific demand, the aggregated demand is not always shown to a single MP at a PRU. Relating this to forecasts it that even if aggregated forecasts have a higher level of certainty (Anupindi, et al., 2014), aggregation of forecasts and call-offs is not done at the moment. Every MP makes call-offs for his or her articles without consideration to the needs at other PRUs, even if having an aggregation would help both the suppliers and the Purchasing Department. The suppliers would benefit from having a consistent plan sent to them and Purchasing would benefit from seeing consumption changes quicker to re-negotiate purchasing prices or other details in the contract. By introducing FOFF, with one MP being able to see and control the aggregated flow of an article would solve the problem with changing delivery plans and consumption changes not being detected.

6.2.2 Inventory

Inventory is affected by various parameters, for example the material requirement, SS, SSD, MHT, and delivery precision. Since the incoming data for inventory calculations is affected by these parameters there are insecurities found in the correctness of the information. For instance, the SSD is often dimensioned according to the throughput and if the throughput changes then the parameters for the inventory should, in theory, change as well (Segerstedt, 2008). However, this is not always the case at Scania and the more errors and uncertainties that exist in the incoming information, the harder it gets to dimension the inventory levels.

One way to secure the inventory availability is to aggregate the demand of all PRUs since this would allow the supplier to receive a more stable forecast. Once again this is dependent on the parameters
set in the production system. Since the parameters are adjusted individually by each MP, and if the SSD, for example, is extended the demand might be perceived to increase for a short period of time. It is therefore important to have a work instruction of how to handle the parameters within the production system to ensure that the forecasts, and also the aggregated forecasts, are applicable.

The maintenance of the inventory and a regular update of parameters should be done continuously. In fact, in the daily tasks of many functions it is clearly stated that it should be done. The Cover-Time found for the products in the inventory should continuously be revised, as stated by Segerstedt (2008). Segerstedt (2008) further states that this is typically the work of an MP to do this, but what should be more emphasized is the importance of actually doing the revision. Typically the work of an MP at Scania would include the revision of old inventory and the phasing out of inventory. However, due to the many parameters and the vast amount of products and suppliers for which an MP is responsible for it might be hard to both find time to revise and to know which articles and parameters to consider. Furthermore, to be able to analyse the inventory, knowledge about MS Excel is needed. More often than not it is not possible to prioritize between the analyses that have to be done and therefore, for example, old material is stuck in the inventory awaiting revision and sometimes even scrapping. One current project at Scania is the PFEP project which will result in a tool helping the user to analyse the inventory and if there is something to be done. This tool may include warnings and lists of what is most crucial to act upon at the moment which will help the user prioritize actions. The PFEP could therefore enable the users to become more proactive in their work and detect problems before they occur.

One of the material handling systems, SIMAS, is used by all the studied PRUs but how the system is configured varies. This makes comparing the work of different PRUs hard. The availability in inventory is also affected, for instance if many PRUs show an urgent lack of material it might not be as urgent at some PRUs as at others. In Figure 38 below the different perceived demands depending on the configuration are visualized and compared to the actual demand time.

![Figure 38 A visualization of when a demand occurs in SIMAS due to the chosen configuration compared to the actual demand time on line, based on Figure 33 (page 57).](image)

Additionally, the configuration of deduction of material from SIMAS, or other similar production control systems, causes problems in the inventory levels when the picking of material is started. Once the instructions for picking have been printed from the production control system, it is possible to start
the internal supply methods such as kitting and sequencing. The printing of the instruction is therefore similar to what Jonsson and Mattsson (2003) refer to as physically reserving material since it disappears from the system and cannot be used for anything but for the picking order printed.

In other words, once the printing of the instruction is done the production control system consider the material as not being available and it is not shown in the system anymore. What the system does not take into account is that often many instructions can be printed beforehand. The printing is sometimes done one day before the production order is placed, causing the risk of material being withdrawn earlier than what it is supposed to be. This in turn affects the material call-offs because if there no longer is any material in stock, MC will generate an order and send a call-off even if the material is currently being picked and sent out to the assembly line, or even if the material is already at the assembly line waiting to be assembled. This is due to the two bin system used at Scania and the sizes not being revised frequently enough. This, once again, calls for continuous revision of the parameters within the system as Louis (2006) states that a Kanban system needs to be re-configured if the demand rate changes, but with the surroundings in mind.

By getting control of the material staging and the deduction, the inventory control would increase as well. By not having control of the inventory levels, the tied up capital in inventory is increased due to uncertainties. Having control of the inventory and clearly showing the information in the system would allow the MPs at Scania to ensure what needs to be ordered based on what is available. Further it would allow them to order material when it is actually needed and not when it is deducted, since they would know that there is enough at the PRU right for what is currently being produced. Some of the important input regarding inventory can be seen in Figure 39 below, however, it should be kept in mind that this is on a general level and more information should be taken into account.

*Figure 39 A matching of the input available at Scania with the identified information found in the literature. The configuration in SIMAS and the inventory in general was proved to be of importance.*

If the FOFF project is to become reality all through Scania the different configurations in SIMAS will need to become more similar to simplify the work of the MP. As it is today, the configuration may lead to differences in the need for certain material and if the PRUs are compared. The PRUs deducting material earlier will be perceived to have a greater need of material than the PRUs deducting material later. If the FOFF MP is aware of the different configurations they might handle it in a way that ensures the material is sent to where it is most needed, but it would create extra work for the FOFF MP. A big reliance on the systems is needed from the FOFF MP since the systems work is not done on site. Therefore an understanding of the system and also a greater knowledge of how the work is conducted is also needed. It has been said that the production would have a greater need of a system with information updated in real time, whereas others advocate the information needed is already there in the system and it just needs to be brought forward. How often MC and SIMAS are updated could affect the work of an MP who is not able to check the Physical World to a greater extent. Therefore, there is a need for logging information to ensure it is not received too late.
6.2.3 Costs and Lead Times

When acquiring material at Scania the MPs mainly consider the fact that the material needs to be delivered on time, rather than the costs connected to the material flow. The order quantities are adjusted to fill a packaging unit, but otherwise the smallest quantity possible is ordered to keep the inventory down.

The costs connected to the acquired material are mainly controlled by the Purchasing department at Scania and how well they can negotiate with the suppliers. However, it is not only the price of an article that affects the cost of it, also the transportation cost and ordering cost needs to be considered. For deciding the order quantity both the product value and ordering costs are evaluated when using the Wilson formula, Silver & Meal, and Wagner & Whitin according to Oskarsson, et al. (2013). Even if the package sizes are fixed, the order quantity should be evaluated each time the consumption of an article is changed. The transportation costs are a big part of the total cost when acquiring material and many times trailers are not filled to capacity.

Since a few years back Scania has the responsibility for all transports, this means that they have the possibility to optimize routes and work with filling the trailers as much as possible. This is the role of the Control Tower, but their work is quite limited due to all the changes done in the call-offs and they need to re-optimize their solutions every day when transportation bookings have been done. The Control Tower has the possibility to move planned call-offs to help with the optimization of routes, but only as long as it does not affect the production. Since the delivery plans are updated daily at some PRUs the Control Tower needs to re-optimize the transportations each day, and this may affect the delivery plans in its turn since planned call-offs might be moved.

One task of an MP today is to check if the suppliers have booked the transports in time for the next day, and the day after check if the booked deliveries have been picked up. The transports that have not been booked or picked need to be resolved, by for instance by speed transports paid for by the supplier. Revolving issues with transport result in extra administrative work, not only for MPs but also for Internal Logistics. If a supplier will not be able to send a delivery in the time promised, they should not book a transport in Webstars and notify the MP as soon as possible. This system means that every time a supplier forgets to book a transport they risk paying for an extra transport in order for the transport to be delivered the coming day instead. However, with a delivery precision of 95 %, the aim for all Scania suppliers, the likelihood of a delivery not being ready is quite small. This means that in 95 % of the time the suppliers need to book a delivery in Webstars.

There are also different ways to measure the delivery precision. Jonsson and Mattsson (2003) divides the delivery precision into two aspects, delivery accuracy and delivery precision. At Scania these two aspects have been combined to define the delivery precision. Measuring both quantity and in delivery time might prove useful at times, but it might also be relevant to measure them separately to get better statistics of what and where the problem actually is.

To get the deliveries in time the lead times need to be considered when making a call-off, both the transportation lead times and buffer times within the system according to Segerstedt (2008). The SSD and buffer times are controlled by the MPs and are revised when there is time. However, these need to be revised regularly when working with a Kanban system according to Louis (2006) and this could also be applied to other order quantity methods.
It can also be assumed that in any company financials, and therefore costs, are of importance. It plays a role in every aspect, for instance when purchasing and transporting material. Therefore, in the summary of Costs and Lead Times in Figure 40 below, it has been illustrated in a general way to symbolize that it is of concern at many levels. In the same way there are many aspects to lead times, and the figure presented below some of the information identified.

![Figure 40](image)

*Figure 40* A matching of the input available at Scania with the identified information found in the literature. The lead times for material and costs found in the material flow affect the total material flow in many aspect, therefore this is a general figure.

If the FOFF project is to be realized for all of Scania, some of the responsibilities of the Control Tower will be moved to the regional MPs instead. The regional MPs will have the control of all the deliveries from a supplier and it will become easier to optimize the routes of the trucks since the puzzle pieces will be larger. The regional MPs will also be able to move call-offs and optimize the deliveries to each PRU, and trailers will not have to be on the roads empty to the same extent, since material will be transported both ways between the sites. The delivery lead time is decided by if it is a bought product or not, and by purchasing goods the lead time depends on the routines of the suppliers according to Segerstedt (2008).

### 6.3 Information for Smart Material Flows

*Cyber-Physical Production Systems* and *Smart Factories* are part of *Digital Factories* which in turn can be summed up within the field of *Industrie 4.0*. When comparing the four cornerstones of *Cyber-Physical Production Systems* the *Physical World*, *Data Acquisition*, *Cyber World*, and *Feedback/Control*, as described by Thiede, et al. (2016) and visualized in Figure 17 (page 33), the three main areas as described by Virtual; *Smart Analytics*, *Real Time Communication and Visualization*, and *Physical Web for Manufacturing*, (Virtual Manufacturing, 2017) common factors can be traced between literature and reality. When Thiede, et al. (2016) talk about the important input to their *Physical World* in terms of demand and supplier information and how the processes are connected, Virtual complements with information regarding actual takt time, location of data collection, type of material, routing of material, decision rules, and working schedules amongst other things in their *Smart Analytics*.

The *Data Acquisition*, gathering of the data in real time and generation of estimations can also be compared with the *Smart Analytics* category of Virtual. Emphasis cannot be expressed of how important it is to have enough information, also the correct information (Virtual, 2017). Virtual prefers to first collect the data, then retrieve relevant information and after that use the data. In relation to collecting the correct information Virtual has worked with tools such as pick-to-light and pick-to-voice. These tools can increase the accuracy of information in the system, but indications have been made that they are not fully developed and errors can be found. (Virtual, 2017)
Comparing the Virtual way of reasoning as to how a factory can become digital with information gathering, it is important to have data transfer protocols, which are represented and presented with the semantic and the understanding of the data in place (Thiede, et al., 2016). Thiede, et al. (2016) also focuses on the gathering of data and that it may even be collected in real time with consideration taken to where the information is collected.

The continuous study and collection of information is something which Almeida and Azevedo (2011) also take into account when studying the factory performance based on data measurements and formulating performance estimations. By taking factors of the Physical World such as seasonality, trends and fluctuations into account, and from that generate predictions, warnings can be received earlier and generate decision support. The traceability of information, brought up by Theide, et al. (2016) in Feedback/Control and by Virtual in the Physical Web for Manufacturing, is also studied by Almeida and Azevedo (2011) to ensure that the predictions are relevant. Further, the Flow Logic, as described by Wikner, et al. (2016), and the through-engineering by Deolitte AG (2015) press on the importance of having a structure in the information collected, and also what should be done to the information. Having this basic structure in place allows for a more effective analysis and perhaps better understanding of the correlations that can be made within the company.

The two other categories of Virtual; Real Time Communication and Visualization, and Physical Web for Manufacturing, when compared with Thiede, et al. (2016), offers an in-depth understanding of the importance of using the information in daily management and analyses in real time, automatic control, and also traceability of information. Many of the aspects of feedback and communication is possible with the usage of BI tools, in for example the usage of reports and dashboards, as described by Loshin (2013). Correlation of estimated prediction as mentioned by Almeida and Azevedo (2011) and the BI tools mentioned by Loshin (2013) could very much be possible if information is gathered continuously and revised by using forecasting and predictive models.

The idea of having a Digital twin of a factory, a Cyber World, is not unachievable as long as there is a good usage of the data available. The Physical World and the Cyber World should reflect each other not only in the daily work, but also in regards to improvement projects to ensure valid simulations and analyses (Thiede, et al., 2016). Virtual mentioned Volvo as one of their customers that have successfully implemented a digital twin of their physical factory, which executes production plans hours in advance to be able to be more reactive in the production process. Lee (2017) point out that there are often difficulties found when using simulation software, especially since the production software is lacking. Since it seems as if Volvo has managed to simulate, make risk analyses, and conduct what-if manufacturing, it is not far into the future before more companies start to conduct the same type of movement towards the smart and Digitalized Production.

Overall the four cornerstones of Thiede, et al. (2016) cover most part of the three definitions of Smart Manufacturing of Virtual. When applying the Scania Smart Pyramid correlations can be found. The Flexible Standardized processes, at the bottom of the pyramid, all through Connected Technology, Data Gathering, and Data Analysis, to Intuitive Presence and Predictable Future are matching both Thiede, et al. (2016) and Virtual (2017). The flexible standardized processes at Scania should pose as the base of the data collection and reflect the Physical World and the processes and transformations conducted. Having connected technology, for example using MES and SCADA allows for information gathering, and also a greater traceability of information within the system. The Cyber World is, similar to the Data Analysis level in the Scania Smart Pyramid, a place where data is studied to later be
Forwarded to the Feedback/Control, or as in the case of the Scania Smart Pyramid, give information in regards to Intuitive Presence and Predictable Future. All in all, there are similarities in the theories of how the work of a smart and Digital Factory should be conducted, as can be seen in Figure 41 below, where the cornerstones of Thiede, et al. (2016) (Figure 17, page 33), the definitions of Virtual (Figure 34, page 61) and a dissected Scania Smart Pyramid (Figure 2, page 3) can be seen together. Since the definitions of Virtual are very broad and fit into many concepts, they have been above the other two in order to symbolize that they reflect many of the categories of both Thiede, el al. (2016) and the Scania Smart Pyramid.

In other words the correct thinking is in place at Scania, towards becoming smart and more digitalized. How the journey will look like may not always be very clear, though. Therefore, the Factory Template by Almeida and Azevedo (2011) can be used as a base for comparison and the first stepping stone towards having a smart material flow in combination with Figure 41 above. The first part of the template consists of working with industry best practises. The later parts of the template concern that there should be a knowledge of how the information needed is connected and also how the functions are using the information. What information that is analysed need to be discussed, as well as what reporting that is needed by each function and process. What information that should be shared and what KPIs to use by the company is also connected to this.

In relation to Figure 41 above, the concept of IMJ can be applied with its focus on Availability, Quality, Capitalisation, and Mind Set. By focusing on these four aspects it is believed that a base of information can be acquired, much in similar to Thiede, et al. (2016), Virtual (2017), and the Scania Smart Pyramid. The information collection has already been started, and this proves once again that the correct mindset exists at Scania, even if the knowledge might not be spread throughout the organization.
With that said, much focus of Industrie 4.0 should be put on the computer systems used within the production. The interfaces between systems such as ERP, MES, and SCADA should be in place in order for the correct information to be gathered and shared between systems. In the description made by Ganesh, et al. (2014) of ERP it is stated that the system should help the organization to collect and use relevant information. The time-relevance of information should be taken one step further in order to allow for analyses, decision support, and relevant information, especially when working with Industrie 4.0 and Digital Factories (Virtual, 2017). The structuring of the data puts pressure on the currently available IT systems in terms of understanding the company’s own network and internal communication (Deloitte AG, 2015). However, indications have been made that to fully understand and structure the data within a company there should be actions taken internally due to a lack of knowledge and actors in the market (Wikner, et al., 2016).

The production systems are to some extent developed at Scania but not fully used, in the shape of MONA, EBBA, and DIDRIK amongst other system. A MES system should provide a base for production planning, operations management and production managements (Mehta & Jaganmohan Reddy, 2015) and the functionality of EBBA in regards to being able to calculate when material is needed is a good base for a future with a complete picture and real-time updates in the system. However, even if EBBA is updating regularly, it is not reflected in all systems and this could possibly create a gap in the Physical World’s information and the Cyber World’s information. Furthermore, EBBA is not implemented at all PRUs, making the gap between the Physical and Cyber World even greater.

The same way of reasoning can be followed for DIDRIK, which for example keeps track of the takt time in the production. This information could be taken one step further and perhaps be matched with taktin in the material logistics. According to the Factory Template by Almeida and Azevedo (2011) industry best practises is a good example of how information could be used. As concluded by Virtual, many companies have been successful in their work towards becoming Digital. Volvo is one of those successful companies and can pose as an inspiration in the setting up of a Digital Factory. But perhaps, before having a real-time simulation of the Scania production, the currently available information and data can be used in a better way, and this should be investigated further.

The possibility to use dashboards based on the production progress is a good base for the future of Operational BI. Other tools include the already in-use system QlickView which has made it easier to understand and evaluate for example supplier delivery precision. However, the use of dashboards and similar tools could be applied for more purposes such as helping the PP, MP, and internal logistics to name a few, knowing the status of the production line with for example red, green, and yellow colour coding.

In terms of decision making, which is believed to be one of the major advantages of having a digital manufacturing system, it may become easier with Industrie 4.0. Wikner, et al. (2016), Thiede, et al. (2016) , and Deloitte AG (2015) emphasize the possibility to provide autonomous help to both the production process itself and the decision making. Wikner, et al. (2016) further make a point of that the tactical decisions should be done as automatically as possible by the system, whereas the strategic decisions should get help by the system to make decisions. Having this implemented more to the material flow at Scania would perhaps primarily help in the daily tasks. For instance, the work of continuously going through Maty-warnings, as done by the MPs daily are sometimes unnecessary and perhaps also the checking of Webstars could become more automatic. In the longer perspective, time would become available and focus put on more strategic decisions and also training of the personnel.
Further, if more decisions are done automatically focus could be put on urgent tasks. Stock and demand variations could be studied into more detail with the help of the system and also making inventory analysis could become a larger part of the everyday work as a road towards continuously improving the material flow at Scania. However, once again, in order for the decision making to take place the correct information must be available, at the right time.
7 Conclusion

In this chapter the general conclusions made within the project are presented. The conclusions are based on the data collected at Scania, but have been generalized to be applicable on any manufacturing company working with assembly of products. Also, a roadmap based on the findings and analyses is presented to make suggestions of how to work more towards becoming a Smart Factory can be done.

The material flow is complex with multiple aspects affecting the flow and at the same time there are multiple functions, with their own specific needs, that are affected by it. The different functions need to be willing to share information amongst each other to ensure the same information is considered when decisions are made. Also, the functions need to work together and towards the same goals and visions to make the material flow work properly. There exist differences between how work is conducted at the PRUs in Södertälje and the PRU in Zwolle, however, these are marginal and do not affect the information needed. Some of the differences include the preferred systems and how daily tasks are performed. How the information flow in regards to the material flow, identified in the study, is shown in Figure 42 below. Since the information flow did not differ between Södertälje and Zwolle one map was created, however there are indications that many functions could benefit from having more transparency between the functions and between the different PRUs.

In the material flow four types of information has been identified to be needed to plan the movement of material. These are the material demand, in the form of a forecast, historical consumption, gross demand, or production plan, as well as the current inventory level, the lead times, and the costs regarding the material flow and ordering. At Scania this information is available, as shown in Figure 43 on the next page, and can be accessed through different systems, but it is not clear throughout the organization how it is accessed and processed. Nevertheless, these four types of information should be seen as a base of what information that should be in place also in the case of Industrie 4.0 and to achieve an Intuitive Presence and Predictable Future.
By having relevant, updated information in regards to these four types of information, decisions about material and orders can be made according to guidelines established within the company. How the guidelines and rules are formulated depends on the consumption pattern of an article, as well as what strategy the company has when producing. For this to be realizable the information must be easily accessible and clearly displayed for the users, and they must know what to use the information for and how.

However, it is not enough for the information to be easily accessed and clearly displayed. The quality of the information also need to be up to a certain standard. There is no established standard for information quality in general, but within a company the same standard should be used. The information used must be relevant, both time wise and for the purpose it was acquired for, but also correct and interpreted in the same way everywhere within the organization. Apart from this, one of the aspects regarding the usage of information, is that the presented information is trusted by the users. If the users neither trust the information, nor the system used, the information will not be used and extra work will be done to ensure the correctness and relevance of the information.

Establishing a standard for how information should be used and interpreted is one step on the way of becoming smart in the material flow. Even so, the need of having a standard for how work is conducted and how information is spread throughout the company is important to acknowledge and work on to be able to maintaining the information quality and relevance of it.

One of the main steps of becoming smart is to create a standard for what information to collect and use, but also for how to use it. This type of standard is used for knowing what information to base analyses and decisions on, and should be stored in the same place and be accessible for everyone. A common database, or data lake, can be used to collect, store, and correlate information between functions, allowing the information to be retrieved and used whenever needed. This enables both willingness and connectivity within the organization, which has proven to enable more efficient ways of working.

To keep the information updated and relevant it must be reviewed continuously. This needs to be included in the daily work of the person responsible for the procurement of material if an organization wants to become smart within the material flows. If the information is not kept up to date and standards are not followed, implemented BI tools will not be as helpful as they possibly could.
Once a standard for information quality and usage has been established the data collection can start. The information following the standard will be useful when applying smart tools such as automatic decision making and display of relevant warnings. Also more advanced tools such as data mining and having a virtual copy of a process will also be applicable, once all the relevant data has been collected.

Ensuring conformity in the decision making and in the handling of information is important, especially if correlations are sought for. Therefore, the collection, storing, processing, and reviewing of information, as shown in Figure 44 below, are needed actions for the shared data and information to be spread throughout the organization. Thereby, decisions regarding the material flows will become Intuitive and the future material flows Predictable.

Figure 44 A roadmap towards becoming smart, summarizing some of the most important steps.
8 Recommendations to Scania

Since the study was initiated by Scania IT to gain a greater understanding of how the production systems are used within the organization, recommendations have been formulated having Scania and Scania IT in mind. As concluded by the analyses emphasis must be put on understanding the processes of the organization before engaging in Industrie 4.0 completely. However, below follows recommendations on actions that can be done by Scania on the road of becoming part of Industrie 4.0. All actions are in need of further research, but are important to enable the usage of smart tools.

To be able to digitalize the assembly and become part of Industrie 4.0, standardization of the Physical World must exist, as well as a standardization of how information is handled before proper intuitive presence and predictable future are realizable. This should be considered as a prerequisite in the process of becoming smart and a general overview can be seen in Figure 45 below.

![Figure 45 The recommendations placed on the concluded roadmap.](image)

By doing this Scania and Scania IT will have taken a step on the way to have a predictable production and an intuitive presence and a part of Industrie 4.0. More importantly, a proactive work in the material flow can be achieved by knowing things before they happen, for example shortages and warnings. Overall, emphasis should be put on that the currently available data is something that should be focused on. Knowing the connections in the data, what it can be used for and work with the data in real-time is an important steppingstone towards becoming smart and part of Industrie 4.0.

As can be understood there are many actions to be taken before Scania can call themselves a part of Smart Factory. The benefits of becoming smart, from the perspective of this study, include better material and inventory control, assembly line status, transparency in the information, more efficient work and decision making.

8.1 Standardization of Information

Standardizing information and how it is composed makes it easier for later tasks such as gathering, using, and sharing data. By having this base set, implementation of new sets of information and software will have a standardized interface. Furthermore, it becomes easier to compare both PRUs and functions with each other if the information is continuously updated and also configurated in the same way.

Overall focus should be on updating the information and data available, especially if it can be used in real-time. Since one big advantages of smart material flows is to be able to react in real-time, real-time information should be used as extensively as possible. Having a standard for the Physical and Cyber World could help in making better usage of the currently available data for it to be used in real-time.
As of now many of the differences between functions and systems makes it hard to fully utilize relevant information.

8.1.1 Common Language and Configurations
The standardization of the Physical World is related to the tasks conducted by each function. For information and progress to be shared and understood between the functions, a common language should be in place.

For example, the usage of delivery precision and how it should be measured is not the same throughout the material flow. Some functions only study the inbound material which includes the Scania controlled transports, whereas others prefer to measure the picked up goods as delivery precision, and this is something that should be standardized in order for proper comparisons to be made. During the conducted interviews, it was discovered that different terminology was used at the PRUs, which can cause confusion if comparisons are made.

Furthermore, the configuration in SIMAS should become more homogeneous and standardized. This is especially the case if the FOFF project is to become reality since it will become more important to know when and where the material is needed when the MPs work from a distance even with a local contact person. Keeping SIMAS with the current set-ups only generates insecurities in the systems where it is unclear where information currently is and when is has been deducted. Additionally, this is a problem when studying the material availability and the setup is not known by the MP, risking to cause urgent call-offs even when it is not needed.

8.1.2 Automatic Decision Making and Reduction of Warnings
Another way to standardize the Physical World and Cyber World includes reduction of unnecessary information. This is especially the case for the MPs, whose role currently is very reactive and if time was made available focus could be put on proactive tasks instead, such as managing the inventory and optimizing call-offs. This means that a system that only warns when necessary is desired. One example of unnecessary warning are the Maty-warnings which the MPs work with. Some MP look at them and simply reject them, since the warnings were already known. Others look at the warnings as a guide in their daily work. This indicates multiple sources of information usage, and if the user in question already knows about the warning the daily work simply consists of closing down unnecessary warnings. By making sure everyone has the same information the amount of Maty-warnings could be reduced, and perhaps not even used at all if an in-depth understanding of the system exists.

Related to the unnecessary work is the control of the Webstars warnings. The concept of Industrie 4.0 is easy to apply when studying the checking of the system when a transport is booked or not. As of now an MP needs to study Webstars before the booking of transports should be done and therefore react on the warnings before they even occur. This time could perhaps be used on other things, such as strategic decisions if the work in Webstars should be done more automatically.

Currently the aim of Scania is to have a delivery precision of 95%. This means that in 95% of the cases the suppliers need to book a delivery in Webstars. However, if the transports were booked automatically as soon as an order has been placed with the supplier, the supplier would only need to cancel the delivery in 5% of the cases. This would decrease the work load of the supplier making it easier to deliver to Scania, but also the Control Tower would be able to only optimize the call-offs and have less re-optimization to do each day. Working like this would allow for further automatic decision making and monitoring, a big part of Industrie 4.0.
Other possible autonomous actions that can be realized are call-offs set to be manually handled even if there is no need for it. By having a more complex IT-system that acts on the given information, the dimensioning of inventory and the call-off sizes can be optimized to help everyone from Purchasing to Internal Logistics. Also, dimensioning the inventory when old material is being replaced by new ones has previously required many hours, but with a system that helps the users in the decision-making this could be optimized.

With a system that reacts in real-time, and perhaps even before an event occurs, would allow preventive work to be done. If the production is simulated hours in advance, faults and issues could be detected. Furthermore, if the production system keeps track of the production status, better picking instructions can be created to help Internal Logistics to focus on conducting the right actions and deliver material at the right time. Additionally, following the production in real-time can be connected to the deduction of material. If the deduction was done in real-time, the Internal Logistics, but also other functions, would know exactly how much material that is still available.

8.2 Information Usage

If a standard of how information and data is stored and presented, a good foundation is created. However, to ensure this a standardization within the usage of the information is needed as well. It is important that all parts of Scania have access to the same information and are willing to share information with one another.

8.2.1 Share and Trust the Information

Currently at Scania the information usage differs between functions and sometimes it may even differ within a function, which makes the users questions the trustworthiness in it. This could be due to different levels of knowledge and ways to perform a task, but another reason that is likely is that everyone does not have access to the same information and therefore must create their own ways of working. An example showing both the differences in the information access and the different ways of performing a task is “Huvudlistan”. This is a table some PRUs have access to through MC which can be downloaded and analysed in MS Excel. It is not everyone that has access to this file, and even less staff have the knowledge of how to do analyses by using the file in MS Excel. The analyses done are not shared within the organization either, which leads to the same type of work being done multiple times.

By sharing some information, and not all information, the trustworthiness of the information can be questioned. It is not certain that the information accessed is correct and updated, which leads to extra work to ensure the information quality and correctness. Therefore, it is important that the information within the organisation is correct, connected, and presented when relevant. However, a part of this is to be willing to share information, which is an important aspect to work with and to have throughout the whole organization.

A good tool to ensure all parts of Scania have access to the same information is the Scania Data Lake. By ensuring that the information in the Scania Data Lake is relevant and up to date, analyses can be made with the data and new knowledge found, but it would also ensure that all decisions are made on the same basis.

An example of where information is scanty, at the moment, is the forecast. The PRUs are allocated a certain number of trucks, buses, and components to be produced each part period, but no further information is shared. More information could be shared with the PRUs to prepare them for what is
coming up. By including more information in the forecast from start, and base it on more data and facts, a more precise forecast might be possible, and the lead times shorter due to moving the COP.

8.2.2 Prioritize in the Same Way

By having the most relevant issues presented and warnings appear, the prioritization will be done for the workers, and everyone will work in accordance to the same guidelines. Also, to be able to sort out information and easily create awareness of what is needed to be reviewed the PFEP may be used.

With the help of PFEP, scrapping of material can be improved since it would become easier to focus on the right material. The same way of reasoning can be applied when material is to be phased out and replaced by new material. Further, the revision of parameters, such as SSD, MHT, and delivery lead times, can be increased and thereby results in cost savings and better usage of the inventory space. What PFEP can do in regards to the revision of parameters includes presenting parameters that should be focused on. The same thing goes for identifying suppliers who are not delivering on time, or if there are quality issues, and this could help both MPs and Purchasing in their work. In relation to forecasts PFEP can highlight consumption changes and warn if something out of the ordinary happens, or if there is a sudden increase or decrease in the material consumption.

The PFEP and Scania Data Lake can be used as steppingstones for having a standard for how to handle information and how to maintain it. But even if all the information is collected in the same place, there must be clear guidelines for what can be done with the tools. If simulations are to be used in the future of the material flows, it is important that relevant information has been collected over a period of time.

8.2.3 The Right Information at the Right Time

Even if there would be more correct information to access, the information needs to be easily accessed as well. This includes the usage of dashboards to show the status of the production, as well as relevant warnings. Visualizing the relevant information and updates makes it easier to get a quick overview of what is needed to be done and may also help in the decision making. The dashboards could show the assembly line status, if there is a risk for material shortage, status of problems, status of transports and whether the transports have been picked up or not, as well as if there are any routines that have to be revised.

The vast amount of systems currently at hand makes it hard to find the most recent and accurate information. Having knowledge of how the systems are functioning is therefore a must for many users today. Even if the systems are meant to show the same type of information there may be differences in how it is displayed and updated. Therefore, the personnel usually require knowledge of how the systems are connected, something which is not always known. This also makes many users question the trustworthiness of the systems since the information displayed sometimes differ. In the long run a common system for the planning functions needs to be in place, not only to ensure the same information available, but also to ensure that the correct information is displayed.
9 Discussion

In the discussion, the generalization of the study has been discussed along with what recommendations that could be suited for Scania and what further research that is considered relevant in the future. Additionally, the method of the study is discussed and how well the plan has been followed. Also, the reliability and validity of the study and what could have been done differently is discussed.

Since this study was conducted at a case company there are limitations as to how generalizable the conclusions are. One example of these limits are the possible improvements found, including those identified by the users, which are not directly applicable onto another company. However, when studying these areas on a higher level, a guide of where problems might exist can be seen and inspiration may be drawn from the recommendations presented when comparing with other companies.

Therefore, it is possible for the general conclusion to be applied to a wide range of companies with a material flow. The need of standardization of what information to use and how it should be used and shared are conclusions that can be applied to all material flows, as well as the need to collect information to be able to have smart material flows. The smart flow would take into account historic and future data as well as aid in the decision making with digital tools, amongst other things. However, in order for this to work, the information must be correct and relevant. Another aspect to take into account is if the information found relevant to use in the material flows in this study, may be limited to only manufacturing companies with an assembly process.

What information that needs to be collected and what connections that can be found when using data mining is something that should be applied to each specific case. Both the further academic research and companies own initiative could help in finding information that is relevant to a specific area of business making better usage of the concept of Industrie 4.0. It can be expected that a well-functioning organization keeps track of the basic information available in the system, and also the information that should be available, indicating that there is a possibility to trace information and also work with BI tools, such as data mining, to a greater extent.

The different types of BI tools available on the market fulfil different purposes, and what type of value that is needed must be considered. If the perceived need is simplifying the work tasks by making the information more accessible, dashboards are to be recommended. If the need is identified to be connected to insights regarding connections in the data, then data mining and Smart Analytics are recommended.

Industrie 4.0 and Smart Factory are relatively new concepts and therefore the result of this study is limited to what needs to be done before implementing smart tools within the processes. Systems used for collection of data are needed as a step towards becoming smart and part of Industrie 4.0, but to be able to utilize the information, information needs to be stored and processed by the right tools. Even if possible tools, such as BI, were taken into consideration, more research is needed in regards to what tools add the most value to an organization. Furthermore, how a standardization of systems and working methods within the systems used at a manufacturing company should be investigated since this would enable the implementation further. Also, to what extent having a simulation of the production in the Cyber World run before the events in the actual Physical World happen should be explored further to take into account factors outside of the material flow such as maintenance.
For Scania, dashboards and decision support seem to be the most suitable tools at the moment, primarily since these could help standardizing the work done at each PRU. The usage of dashboards helps visualize information and compare the different PRUs with each other. Also, the dashboards could display work tasks that should be prioritized. One example of this is helping select material that have not had their parameters checked for a long time, something which could be helped by the PFEP project. Then inventory levels could perhaps be decreased and the replacement of old material with new material could be optimized by having better knowledge of what actually is in stock. This can be interpreted as a dashboard with decision support, but other ways of using decision support is automated decisions. These automated decisions do not only rationalize the work, but also helps avoiding the human factor and will therefore reduce possible mistakes.

As for the data mining and Smart Analytics both IMJ and PFEP will prove useful as a base as to what can be done. These projects should work as an inspiration and should therefore be continued. The winnings of having Smart Analytics and using IT systems integrated to the everyday work includes not only being able to act more proactively, but it would also allow for faster reactions and decisions if something does not work according to plan. Another aspect that data mining takes into account is that more patterns in the organization will be found, as well as in the transformation processes. It will allow knowledge that prior has been taken for a gut feeling, to be tested, evaluated, and also become known to the whole organization.

The limitations to this study connected to Scania include the focus on a user perspective and not how realizable the conclusion and recommendations are for Scania IT. All processes need to be standardized and that information must be collected have been established, but not how that work should be conducted. One way is to standardize the systems to make them easier to use, and not allow for local solutions. The standardization of the work should, however, be done before data is to be collected, to ensure that it is possible to compare the data. Another limitation to this study was not taking the system architecture into account. This would affect how the recommendations are to become reality, but due to lack of prior knowledge and the time limit it was not possible to study the architecture in greater detail.

The method for data collection at the case company has been extensive to create an understanding for how work is conducted and what information is actually used. At the start of the project the focus was on the material planning function which resulted in the whole project having its standpoint from this function. This might have affected how valid the results are in connection to the other functions, but to minimize the risk of the conclusions being invalid, multiple people at each function were interviewed. This increases the reliability of the collected data at the case company and potential gaps in the data collection was filled. This also highlighted areas that were extra troublesome or important to the users of production support systems related to the material flow. All interviews were transcribed and sent to the interviewee to minimize the risk of misunderstandings and all facts were then anonymized to enable more open interviews and discussions.

Limiting the scope of the study at the case company was hard due to the size of the company and the lack of knowledge within the organization of how all functions are connected. This led to an explorative approach were interviewees referred to new possible interviewees that could be of relevance to the study. As the work proceeded more functions affecting the material flow were detected and investigated, to be able to get as broad of a picture as possible of the material flow. The delimitations done at the beginning of the study remained unchanged and the researcher did not deviate from these
which helped in not making the scope bigger than was already established. One way to go could have been to limit the research to a smaller part of the company and the material flow, but this would have resulted in conclusions that would not have been as applicable to the whole company and the generalizability would probably have been lessened.

The time plan has been followed throughout the project, but some changes have been needed to adapt to circumstances that could not be affected by the researchers. This included the rescheduling of the study visit to Zwolle as well as the meetings with the supervisors. When these type of circumstances occurred in the plan was revised and the time utilized in other ways by conducting tasks that were not directly related to the delayed tasks and preparing the upcoming work as much as possible.
10 References

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[Använd 7 March 2017].

[Använd 6 March 2017].


List of Conducted Interviews

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Anna-Karin Näslund
Arjan Thomassen
Bert Uitslag
Christer Svensson
Daniella Bjälevik Lyhrén
David Chauca
Douwe van Unen
Eduardo de Paula Silva
Erik Karlsson
Erik Söderberg
Fredrik Vidlund
Henk Meijerman
Henrik Hellstadius
Jan Graveling
Jerry Kluitenber
Joakim Danlid
Joakim Ersson
Johan Lag
Lars Hanson
Lina Hagström
Linnéa Dunge
Magnus Lundin
Marcellino Buitenhuis
Neimo Saad
Niklas Råvik
Nina Jonasson
Odd Rune Jacobsen
Per Andersson
Peter Lööv
Petter Andersson
Pontus Hellgren
Roger Ahlenius
Simon Bork
Stefan Hermansson
Tommy Bodin Bjarm
Urban Wistrand
Willem Pronk
Daniel Sterner
Appendix A - Interview Questions

The following questions were used during the interviews with some adoptions to fit the interviewees and their roles.

What is your background?
For how long have you worked at Scania in your current position?
Have you had any other roles?

What tasks are included in your daily work?
What are you responsible for?
What are the goals of your working process?
What do you expect of the people in your team?

What information is sent out in every step?
What systems do you use?
What parameters are you mainly looking at? Which ones do you get to decide?
How do you work with these parameters?
What are you looking for when updating the parameters?
How do you follow up on your work?
Do you conduct any analyses of your work or does someone else do it?
Do you conduct any analyses and how?
How do you retrieve information? Do you get it served or do you collect it yourself?

What other functions are you in contact with?
What do you control and what does other functions control?
Would you benefit from better communication between different function?
Why and how?

Do you compare your working process with your colleagues, do you learn from each other and other PRUs?

Is there any data that you would prefer to have updated/analysed in real time?
What data do you require faster?
Do you feel today that some processes could be done automatically?

If you were given a dashboard to put anything you wanted on, what would you put there? Are there any types of information missing today?
Appendix B - Equations

Equation 1 The Wilson Formula (Oskarsson, et al., 2013)

\[
\text{Wilson Formula} = \sqrt{\frac{2 \times K \times D}{r \times p}}
\]

\(K = \text{Ordering cost}\)
\(D = \text{Yearly demand}\)
\(r = \text{Stock interest}\)
\(p = \text{Product value}\)

Equation 2 The Silver & Meal Algorithm (Jonsson & Mattsson, 2003)

1. Calculate the cost of ordering the demand needed in period 1
\[ c_2 = s \]
2. Calculate the cost of ordering and storing the demand needed in period 1 and 2, in period 1.
3. Compare the average cost of ordering for period 1 and 2 to the cost of only ordering for period 1. If the average cost of ordering for the first two periods is lower continue to calculate the cost of ordering period 1, 2 and 3 in period 1
4. Continue to calculate the average cost for ordering for more periods until the average cost is higher than ordering for one period less
5. Continue to do so until orders for all periods have been planned

Equation 3 The Wagner & Whitin Algorithm (Wagner & Whitin, 2004)

1. Calculate the cost for ordering the demand needed in period 1
\[ c_1 = s \]
2. Calculate the cost for ordering the demand needed in period 1 and 2 in period 1
\[ c_{12} = c_1 + i_1 \times d_2 \times p \]
3. Continue to do the same for all periods \(t, t = N\)
4. Calculate the cost of ordering the demand needed in period 2 separately
\[ c_2 = s \]
5. Calculate the costs of ordering the demand needed in period 3, and all other periods respectively, choosing the cheapest alternative for period 1 and 2, \(c_{12} \text{ or } c_1 + c_2\)
6. Continue in the same way until all cost alternatives for all periods are calculated (step 5)

\(d_t = \text{Amount demanded in period } t\)
\(i_t = \text{Interest charge per unit of inventory carried forward to period } t + 1\)
\(s = \text{Ordering cost}\)
\(x_t = \text{Amount ordered}\)
\(p = \text{Product value}\)
Equation 4 Little’s Law (Anupindi, et al., 2014)

\[ I = R \times T \]

\( I \) = Average Inventory  
\( R \) = Average Throughput  
\( T \) = Average Flow Time

Equation 5 Calculation of utilization in relation to capacity (Jonsson & Mattsson, 2003)

\[ Utilization = \frac{Produced\ volume}{Nominal\ capacity} \]

Equation 6 Calculation of the Inventory Turnover Rate (Jonsson & Mattsson, 2003)

\[ Inventory\ Turnover\ Rate = \frac{Value\ of\ delivered\ goods}{Average\ capital\ tied\ up\ in\ the\ material\ flow} \]

Equation 7 Safety Stock, with uncertainties in both demand and lead time based on SERV1 and SERV2 (Oskarsson, et al., 2013)

\[ SS = k \times \sigma \]
\[ \sigma = \sqrt{(\sigma_D)^2 \times L + (\sigma_L)^2 \times D^2} \]

\( k \) = safety factor  
\( L \) = Lead Time  
\( D \) = Demand  
\( \sigma_L \) = standard deviation of lead time  
\( \sigma_D \) = standard deviation of demand

The \( k \) value is found in a table correlating the service level with the safety factor for SERV1.  
For SERV2 the \( k \) value is based on \( f(k) \)and later found in the same way as for SERV1

\[ f(k) = \frac{(1 - \text{Serv}2) \times Q}{\sigma} \]

\( f(k) \) = the service function, where the value of \( f(k) \) is matched by a \( k \) value  
\( Q \) = order quantity  
\( \sigma \) = standard deviation, calculated in the same way as above
Equation 8 Calculation of the Reordering Point (Segerstedt, 2008)

\[ \text{Reorder Point} = P_L + kMAD_L \]

\( P = \) most recent prognosis
\( L = \) lead time
\( \text{MAD} = \) Mean Absolute Deviation for the prognosis period
\( t_p = \) prognosis period for which the most recent prognosis is valid
\( t_L = \) lead time and inspection interval
\( P_L = \) expected average demand during lead time and inspection interval
\( P_L = \frac{t_L}{t_p} \)
\( \text{MAD}_L = \text{MAD for lead time and inspection interval} \)
\( \text{MAD}_L = \text{MAD} \sqrt{\frac{t_L}{t_p}} \)

used if the prognosis error at different time points is assumed to be stochastic
\( k = \) the probability of lacking material

Equation 9 Calculation of quantity needed to refill to Base Stock (Segerstedt, 2008)

\[ T = d(P + L) + z\sigma \sqrt{P + L} \]
\[ \text{Average inventory level} = \frac{dP}{2} + z\sigma \sqrt{P + L} \]
\[ Q = T - \frac{dP}{2} + z\sigma \sqrt{P + L} \]

The value of \( z \) is retrieved from a Normal distribution table, where \( N(0,1); P(\xi \leq z) \).

Each time period the inventory is refilled with \( T \) deducting the outstanding orders and the currently available stock.

\( d = \) average demand during time period
\( \sigma = \) standard deviation in of demand during time period
\( P = \) amount of time periods between each restock
\( L = \) lead time, time from ordering until it is available in inventory
\( T = \) replenishment level
\( Q = \) average ordering quantity

Equation 10 Calculation whether an order needs to be done according to Cover-Time Reviewing. (Segerstedt, 2008)

\[ \text{Cover time} < \text{lead time (including inspection interval) + buffer time} \]

Equation 11 Kanban lot size calculation (Louis, 2006).

\[ \text{Kanban Lot Size} = \frac{(\text{Average daily demand}) \times (\text{Replenishment lead time} + \text{Safety Stock})}{\text{Kanban Order Quantity}} \]
Appendix C - System Overview

Below is a list of the systems mentioned in the Current State in alphabetical order.

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGDA, Adaptive Gross Demand Administration</td>
<td>System combining the known demand with the forecasted demand for the coming twelve months.</td>
</tr>
<tr>
<td>AROS Production</td>
<td>Keeps track of all the articles used within the production. Purchasing adds new articles here and Packaging Technicians sets the information regarding packaging. To be replaced by another system.</td>
</tr>
<tr>
<td>Deviation System</td>
<td>A list of deviations in the receipt of products used to help the material planners keep track of deviations.</td>
</tr>
<tr>
<td>eCarrier</td>
<td>Deviation reporting system.</td>
</tr>
<tr>
<td>Efhekt Baseware</td>
<td>System used for invoice posting.</td>
</tr>
<tr>
<td>eQuality</td>
<td>A system for reporting deviations caused by the suppliers.</td>
</tr>
<tr>
<td>FRAS, Follow-up Report Administration System</td>
<td>System supporting the handling of deviations between dealers, distributors, bodybuilders, factory and production amongst others.</td>
</tr>
<tr>
<td>Huvudlistan</td>
<td>A list of articles within the production and information regarding them.</td>
</tr>
<tr>
<td>IACOB</td>
<td>Order management system within Scania.</td>
</tr>
<tr>
<td>iFOT</td>
<td>System for optimizing routes and transports.</td>
</tr>
<tr>
<td>iNet</td>
<td>Manual transport bookings</td>
</tr>
<tr>
<td>MA, Mona Assembly</td>
<td>Several modules to support the local production processes and product and process preparation. Contains for example product structures, material and component supply, and delivery schedules.</td>
</tr>
<tr>
<td>Master Calendar</td>
<td>System for the calendars at Scania regarding working days, part periods and order batches. Used by multiple systems.</td>
</tr>
<tr>
<td>MATRIS, MATerial Requisition Information System</td>
<td>System for purchasing of automotive parts.</td>
</tr>
<tr>
<td>MC, Material Control</td>
<td>Supporting material procurement</td>
</tr>
<tr>
<td>MM, Mona Material</td>
<td>Price setting and accounts from MA and SIMAS to material transactions. Values each PRU’s material. Analyses regarding stock and stock taking. Module for internal parts pricing.</td>
</tr>
<tr>
<td>Mona Systems</td>
<td>The Mona systems are used within the production and is the core to all production processes. It has different modules used by different parties involved from the order to delivery. MA,MC, MM and SIMAS are some of the systems.</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
</tr>
<tr>
<td>Picking</td>
<td>System used for instructions regarding picking for kit, batch, sequencing etc.</td>
</tr>
<tr>
<td>PRAL, Production ALocation</td>
<td>Currently used for mixing and sequencing of production on assembly line to match the desired delivery date. It considers</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Supporting quality process and support the after line process at the chassis workshops.</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Proccess</strong></td>
<td>Supporting quality process and support the after line process at the chassi workshops.</td>
</tr>
<tr>
<td><strong>ClickView</strong></td>
<td>An application for visualizing information in a simple and useful way.</td>
</tr>
<tr>
<td><strong>SIMAS, Scania International Material Administration System</strong></td>
<td>Supporting material handling. Internal material handling, from goods reception to warehouses, repacking and goods dispatching.</td>
</tr>
<tr>
<td><strong>SOTig, Scania Outgoing Transport and Invoice handling</strong></td>
<td>Supporting outgoing transports for non-complete chassis with transports and invoice documents, also supporting invoices for services.</td>
</tr>
<tr>
<td><strong>SPARTA, Scania Production - Adaptive Order allocation and Balancing</strong></td>
<td>Production system replacing systems such as PRAL. Production ordering system at Scania and MAN gearboxes. Production allocation and balancing and after that to take care of all other production flows including IM.</td>
</tr>
<tr>
<td><strong>STAR, Sourcing, Tracking And Reporting</strong></td>
<td>A Volkswagen Group sourcing system.</td>
</tr>
<tr>
<td><strong>TIPS</strong></td>
<td>Supporting batch production, component workshops and manufacturing of parts.</td>
</tr>
<tr>
<td><strong>TRAIL</strong></td>
<td>Used for tracking and tracing material to and from Brazil</td>
</tr>
<tr>
<td><strong>Webstars</strong></td>
<td>Transportation booking system for suppliers.</td>
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</tbody>
</table>