Minimizing the risk of material shortage and waiting times via an improved order to delivery process

A study conducted within IV Produkt in Växjö

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Växjö, 29th May 2013

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Abstract

Master Program in Business process and Supply Chain Management
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Title: “Minimizing the risk of material shortage and waiting times via an improved order to delivery process – A study conducted within IV Produkt in Växjö”

Background: Inventory Management activities have gained a relevant importance over the time in reducing uncertainties at both upstream as well as downstream levels of the supply chain, allowing a smooth material flow between chain members while responsively meeting customer demand. Control activities over the inventory represent a challenged and controversial aspect for most of today’s companies, including IV Produkt.

Problem discussion: IV Produkt has, due to the rapid growth during the last ten years, fallen behind the area of inventory management as well as internal material handling process. The reason is that the company has not been able to develop these functions with the same pace as the economic growth. Consequently, the firm is facing difficulties to efficiently supply assembly lines, causing material shortage and waiting times.

Research questions:

RQ1: - How is the order to delivery process, from material supply functions to the Assembly line 2, at IV Produkt built up today?

RQ2: - How can the order to delivery process of raw material and semi-finished products, between material supply functions and the Assembly line 2, be improved in order to minimize the risk of material shortage and waiting times?

RQ3: - How can the physical storage of raw material and semi-finished products be structured within the studied area in order to support RQ2?

Method: This thesis represents a descriptive case study conducted via a positivistic perspective and a deductive approach. Data was collected by interviews, observations and questionnaires, as well as via academic literature procured via a research in Linnaeus University’s library and via the use of approved web databases. Results are based on quantitative data collected from the studied company, guaranteeing the scientific credibility of the thesis. The respect of ethical principles were ensured by a discussion with company to mutually agree on the confidentiality of the presented information.

Conclusion: The conclusion shows how the studied order to delivery process is built up today, highlighting several kind of waste in the current material and information flows. As a result, several actions, such as an extended use of the data system, the application of Kanban and the implementation of the ABC logic, in combination with a new proposed storage layout, were identified and proposed in order to minimize the risk of material shortage and waiting times.
## Index

1. Introduction .................................................................................................................. 7  
   1.1 Background ............................................................................................................. 7  
   1.2 Problem discussion ............................................................................................... 10  
   1.3 Research questions ............................................................................................... 13  
   1.4 Purpose .................................................................................................................. 13  
   1.5 Disposition............................................................................................................. 13  
   1.6 Time-plan .............................................................................................................. 15  
2. Methodology ................................................................................................................. 16  
   2.1 Scientific perspective............................................................................................... 16  
      2.1.1 Positivism ....................................................................................................... 16  
      2.1.2 Hermeneutics ................................................................................................. 16  
      2.1.3 Scientific perspective of the thesis ................................................................. 17  
   2.2 Scientific approach ............................................................................................... 17  
      2.2.1 Deduction ....................................................................................................... 17  
      2.2.2 Induction ......................................................................................................... 18  
      2.2.3 Scientific approach of the thesis .................................................................... 18  
   2.3 Research method .................................................................................................... 18  
      2.3.1 Research method of the thesis ...................................................................... 19  
   2.4 Data collection ....................................................................................................... 19  
      2.4.1 Data collection approach of the thesis ........................................................... 22  
   2.5 Scientific credibility ............................................................................................... 23  
      2.5.1 Scientific credibility of the thesis ................................................................... 24  
   2.6 Ethical considerations ........................................................................................... 25  
      2.6.1 Ethical considerations of the thesis ............................................................... 25  
3. Theory ........................................................................................................................ 26  
   3.1 Order to delivery process ...................................................................................... 27  
      3.1.1 Material and information flows within the order to delivery process ............... 27  
      3.1.2 Push- and pull- based materials management ............................................... 29  
      3.1.3 Flowcharts ..................................................................................................... 30  
   3.2 Function and tools to improve the order to delivery process ................................. 34  
      3.2.1 Lean and Six Sigma principles ...................................................................... 35  
      3.2.2 Kanban ......................................................................................................... 37
3.2.3 Information and communication system ......................................................... 39
3.3 Inventory management to support material supply ............................................. 41
  3.3.1 Classification of items within the inventory .................................................. 42
  3.3.2 ABC analysis .............................................................................................. 43
  3.3.3 Physical layout of storage ............................................................................ 45
4. Empirical data ........................................................................................................ 48
  4.1 Mapping of the entire order to delivery process .............................................. 48
    4.1.1 Sequence of activities within the process ................................................. 48
  4.2 Material Flow ..................................................................................................... 52
  4.3 The order to delivery process from material supply functions to the Assembly line 2 ... 54
    4.3.1 Flow A ..................................................................................................... 56
    4.3.2 Flow B ..................................................................................................... 57
    4.3.3 Flow C ..................................................................................................... 62
  4.4 Picking frequency of components involved in the order to delivery process ......... 67
  4.5 Operators’ opinions about the daily work .......................................................... 71
5. Analysis .................................................................................................................. 77
  5.1 IV Produkt’s order to delivery process ............................................................... 78
    5.1.1 Overall analysis of the entire order to delivery process ............................ 78
    5.1.2 The order to delivery process, from material supply functions to AL2 ........ 78
    5.1.3 Summary of area for improvements ........................................................... 89
  5.2 Implementation of tools and functions to improve the studied order to delivery process ... 91
    5.2.1 Improvement of the information flow ....................................................... 91
    5.2.2 ABC Analysis .......................................................................................... 95
      5.2.2.1 Distance covered and time spent with an ABC approach .................... 99
    5.2.3 Implementation of Kanban ....................................................................... 102
    5.2.4 Summary of functions and tools to improve the studied process ............... 103
  5.3 New proposed storage layout .......................................................................... 104
    5.3.1 Implementation of ABC logic in the storage layout .................................... 104
    5.3.2 New material flowchart ........................................................................... 109
    5.3.3 Simulation of distance covered and time spent with an ABC approach ...... 111
6. Conclusion ............................................................................................................ 116
7. Reflections ............................................................................................................ 122
8. Action plan .......................................................................................................... 123
9. Reference list ........................................................................................................ 128
9.1 Literature ....................................................................................................................... 128
9.2 Scientific articles ............................................................................................................ 129
9.3 Verbal sources ................................................................................................................ 134
9.4 Websites ......................................................................................................................... 134
10. List of Figures .................................................................................................................. 134
11. List of Tables .................................................................................................................. 136
Appendices ......................................................................................................................... 137
   Appendix 1 ....................................................................................................................... 137
   Appendix 2 ....................................................................................................................... 142
1. Introduction

The aim of this chapter is to identify and describe the research area. A background and a problem discussion will debate the issue and present the company which is the object of the present thesis. The chapter will end up in a specified purpose and research questions to give the reader an understanding of what are the results intended to be obtained from this thesis.

1.1 Background

IV Produkt is a Swedish manufacturing company producing cost efficient and environmental friendly air handling units. The firm was founded in 1969 and its head-office and production are located in Växjö. The vision of IV Produkt is to “develop, manufacture and promote air handling products that are energy efficient, environmentally friendly and tailored to meet customers’ needs” (Fredriksson, Sales Manager, 2013).

IV Produkt has in recent decades developed from a small production firm to a well-established and market leading SME (small-medium sized enterprise), with a preserved entrepreneurship finding its roots in the original vision of the company. Several factors have influenced the business success until today, where two key elements in terms of an entrepreneurial mind-set including a fast decision process in combination with a well pronounced customer orientation can be highlighted as main contributors. The customer portfolio is continually growing so do market demands in respect of a wider range of products to be delivered with a high product quality, shorter lead-times and with a world class delivery accuracy. The business environment in combination with long and medium term strategies given by the management board have led to strategic investments within the manufacturing area, but also the need of optimization and utilization of exiting assets and manufacturing processes (Fredriksson, Sales Manager, 2013).

The customer category served by IV Produkt is represented by installers, which buy the firms air handling units, resell and install them to the final end users (Fredriksson, Sales Manager, 2013), as illustrated in the figure 1. In order to gain customer satisfaction IV Produkt has translated the vision in the everyday business by working towards a differentiation strategy, consisting on producing customized products with a high focus on Life Cycle Costing (LCC). By having this in mind, the company is constantly working to create and deliver the best investment over the time in terms of quality, and to offer the cheapest options in the long-run perspective (Kjellsson, Shop-floor Manger, 2013).
Today the organization is the Swedish market leader, but has felt the limitation of it which has pushed the firm to expand its export operations into most of the Northern European countries. Due to this, IV Produkt has defined an expansion strategy in the European market, so that the goal in the long-term strategy is to reach in 2020 a turnover of 1 billion SEK. To be able to achieve this target, the firm works to increase the efficiency in production, including quality parameters, maintaining the manufacturing process in Växjö (Fredriksson, Sales Manager, 2013). Therefore the company has started to implement basic key elements coming from Lean and the Toyota production philosophy, such as standardization of work and new methods on the shop floor, for example the 5S methodology (Kjellsson, Shop-floor Manager, 2013).

The business environment surrounding IV Produkt is as for many other companies a challenge and the need of a high customer orientation, in combination with continuously improvements, is a must in order to maintain a competitive position on the market. The company has detected delivery accuracy in terms of high delivery reliability as a key value driver towards its external customers. Consequently, a high attention has been given to improvement of internal processes linked to order to delivery flows and the ability to supply internal customers with as high delivery accuracy as possible, following the belief that such exactness will have positive effects on the external performance. The internal supply chain (ISC) within IV Produkt has main and supplementary material supply functions, here after seen as departments or operation areas which are responsible for supply activities taking place after goods reception and before the final assembly, with the aim to support three assembly lines indicating a well-defined internal supply and customer relationship, where each assembly line i.e. the customer, is requiring high on time delivery precisions. The material supply function differs between the lines in accordance with their production aims. Assembly line (1) and (3) are producing six other air handling unit types for example family Envistar, requiring longer lead times including a more complex assembly process. Those lines are therefore using a dedicated picker who prepare, with help of a wagon, a kit of components in accordance with the custom ordered unit and the total kit, covering all needed components, is delivered to the operator assigned for the assembly of the order. Assembly
line (2) titled S-Line 3140, aiming for the assembly of Flexomix units, require shorter production lead times and each operator has to pick and move all components required for the assembly order to the assembly table by himself, and the process (including part of supply functions) is consequently different in comparison to the other two (Fredriksson, the Sales Manager, 2013; Johansson, Workshop Manager 2013; Johansson Manager for assembly line, 2013).

The internal perspective of the supply chain was also theoretically studied by Mattsson (1999). The author argues that such view mode entitles the definition of logistic system limits to correspond to the company limits for the company being studied (Jonsson, 2008). From a logistic point of view, there are traditionally three different functions or blocks that are crystallized within an industrial enterprise: a material supply function, a production function (value-refinement) and a distribution function (Figure 2). These blocks can be seen as the actors within the internal supply chain. Internal actors can be departments such as purchasing department, storage department, semi-product manufacturing, production/assembly unit, customer service department and an outbound/transport department, which are collaborating with the aim to add and refine value along the material flow (Mattsson, 1999). According to Mattsson (1999, p.38), “each of these sections can be regarded as customers and suppliers to each other and it is through their combined efforts that the company can produce and deliver products to external customers”.

![Figure 2: Internal perspective of the logistic system. The own company is the starting point (Jonsson, 2008, p. 39)](image)

The implementation of an efficient and effective management of material flow through ISC is crucial to the chain’s success (Chan & Prakash, 2012). The material flow, meant in the sense of order to delivery process, starts with the identification of needs and ends with the delivery to the customer. These needs could correspond to the necessity to supply a warehouse or to provide material for manufacturing activities (Mattson, 1999). In this way, the process starts with a series of activities connected to the receiving of material from internal material supply chain functions, and it ends up with the logistics activities needed to make the product available and ready to be delivered to the internal customer on the right time (Franklin Liu & Liu, 2008).
Inventory Management activities have gained a relevant importance over the time in reducing uncertainties at both upstream (supply functions) as well as downstream levels (customer) of the internal chain, allowing a smooth material flow between chain members while responsively meeting customer demand (Ryu, et al., 2012; Bendre & Nielsen, 2013). The main object of inventory management is to maintain the stock level of each step of the chain sufficiently stable to meet the requests of customers, by ordering goods from its immediate supplier. The latter is therefore organized as a process where each member gives order to its immediate supplier, in order to have a sustainable level of stock to supply the order of the immediate customer of the chain (Garcia, et al., 2012).

The need by the firm’s management to adopt a suitable inventory management is also required by the fact that the stock level in the different steps of the chain is often inaccurate. Management is therefore needed to adopt an appropriate model of Inventory Control in order to optimize the chosen inventory policy (Hai, et al., 2011). The control activities over the inventory represent a challenged and controversial aspect for a company’s management due to the financial consequences of supplying needed quantity and quality of products to meet both customer’s requirements and manufacturing needs. Keeping raw materials, components and finished products in stock consumes space and tie-up capital, so that it cannot be used in alternative ways (Lambert & Stock, 1993). Several authors explored the concept of inventory control focusing on single specific levels of the stock. In this context, the literature related to the management of raw material (e.g. Pratap & Singh, 2008; Emerya & Marques, 2011; Silver & Zufferey, 2005; Kim & Chandra, 1987) and semi-finished products (e.g. Wanders, et al., 2004) inventory is well debated.

1.2 Problem discussion
Considering the order to delivery process from an inventory point of view, the internal supply chain can be considered as a repetitive process where each supply member is strictly connected to its immediate upstream and downstream level of the chain. When an order is placed on the immediate supplier, there may be a waiting time to the moment the request is satisfied. This time is commonly defined as replenishment lead time and it may be generated by an ordering time-delay or a production/distribution delay. When designing and implementing an inventory replenishment policy, management should carefully consider the instability and undesirable effects which appear as inventory and orders may diverge along the different steps of the chain (Garcia, et al., 2012).
It is therefore important that the firm has a well-developed tactical planning of the material level in order to ensure a continuous material flow and to create value-adding activities. While planning the flow of material, managers should keep a high attention on maintaining a balance between supply and demand, with a high focus on the time and quantity aspects of the flow. In this perspective, Jonsson & Mattsson (2006) explain that there are two main questions which always should be considered in order to develop an efficient material plan, i.e. “When to order/deliver?” and “How much to order?”. According to Jonsson & Mattsson (2006) there are numerous and different material planning methods that can be used, and each of them is aiming to support the firm’s management in order to answer the two questions above described. Those methods tend to manage the quantity aspects in a similar manner, but nearly everyone seems to be unique considering the time aspect. Consequently, the choice of the most suitable method must be based on the company’s specific needs because only in this way it will be possible to ensure a profitable planning of the material (Jonsson & Mattsson, 2006).

Linking this discussion to IV Produkt, the business has, due to the rapid growth during the last ten years, fallen behind within the area of inventory management as well as internal material handling processes. The reason is that the company has not been able to develop these functions and flows with the same pace as the growth of the business. Previously, the business was not in a specific need of an advanced inventory control system since the product range and production volumes were smaller and the internal material handling manually manageable by the production staff. This mentality and approach is still present today, while external demands and needs have changed. Raw material and semi-finished goods are stored randomly, without any inventory structure or material assignment philosophies, in different separated warehouses outside the production/assembly area. Consequently, this has caused a major challenge from a manufacturing point of view to supply each assembly line with required material on time comprising internal transports and physical storage. In other words, the company is facing difficulties to supply their assembly lines on time causing raw material shortage during the assembly process, resulting in production delays or waiting times (Kjellsson, Shopfloor Manger).

The present material flow likewise the inventory structure of raw or semi-finished material from a general point of view within IV Produkt consists of six activities: external suppliers; goods reception; internal transport to external storages; internal transport to internal storage areas, production departments or directly to storage facilities at the assembly line, picking and material movement from internal storage or production units to storage facilities surrounding the assembly
line which are consumed via picking and supply events during the assembly process (Johansson, Workshop Manager 2013). Those activities are described in Figure 3, which is also highlighting the main area of focus for the present thesis, marked by a red square.

Combining the understanding of the present material flow with the challenge already pointed out, indicates that the company has an outdated and non-efficient control over their internal material supply. In addition, resources are allocated on activities that do not add value to the process and ultimately increase their costs, which the customer segment is not willing to stand for.

Figure 3: Material flow within IV Produkt (from inbound flow to assembly line), highlighting the order to delivery process (Dagberg, Thorén, Tozzi & Velichkov, 2013)
1.3 Research questions
Following the problem discussion, the importance for IV Produkt to improve the current handling and supply of raw material and semi-finished products to their assembly lines has become a focus area for the management. On the basis of these considerations, the following research questions are formulated:

RQ1: How is the order to delivery process, from material supply functions to the Assembly line 2, at IV Produkt built up today?

RQ2: How can the order to delivery process of raw material and semi-finished products, between material supply functions and the Assembly line 2, be improved in order to minimize the risk of material shortage and waiting times?

RQ 3: How can the physical storage of raw material and semi-finished products be structured within the studied area in order to support RQ2?

1.4 Purpose
The purpose of this thesis is to provide IV Produkt with proposals regarding how the order to delivery process of raw material, from material supply functions (i.e. all supply activities taking place after goods reception and before the final assembly) to the Assembly line 2, can be improved. In other terms, how right material can be delivered to the studied assembly line on time. Moreover, presented suggestions should give the company a better knowledge about storing alternatives of raw material and semi-finished products with the aim to support the recommended order to delivery process.

1.5 Disposition
The structure of this thesis is based on eight chapters, as shown by Figure 4.

Figure 4: Disposition of the thesis (Dagberg, Thorén, Tozzi & Velichkov, 2013)
In a more details, Figure 5 shows how the different chapters of the thesis (theory, empirical data and analysis) are combined to each other to develop the final conclusion, where the highlighted research questions will be answered.

The order to delivery process, from material supply functions to Assembly Line 2, within IV Produkt

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**RQ1**
How is the order to delivery process, from material supply functions to the assembly line 2, at IV Produkt built up today?

**Order to delivery process**
- Material and information flow within the order to delivery process
- Pull- and push- based material management
- Flowchart

**IV Produkt’s order to delivery process**
- Overview analysis of the entire order to delivery process
- The order to delivery process, from material supply functions to AL2
- Summary of area for improvements

**Functions and tools to improve the order to delivery process**
- Lean and Six Sigma principle
- Kanban
- Information and communication system

**Implementation of tools and functions to improve the studied order to delivery process**
- Improvement of information flow
- ABC analysis
- Implementation of Kanban

**Conclusion**

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**RQ2**
How can the order to delivery process of raw material and semi-finished products, between material supply functions and the assembly line 2, be improved in order to minimize the risk of material shortage and waiting times?

**Functions to improve the order to delivery process**
- Mapping the entire order to delivery process
- Material flow
- The order to delivery process from material supply functions to the Assembly line 2
- Picking frequency of components involved in the order to delivery process
- Operators’ opinions about the daily work

**Inventory management to support material supply**
- Classification of items within the inventory
- ABC analysis
- Physical layout of storage

**New proposed storage layout**
- Implementation of ABC logic in the storage layout
- New material flowchart
- Simulation of distance covered and time spent with an ABC approach

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**RQ3**
How can the physical storage of raw material and semi-finished products be structured within the studied area in order to support RQ2?

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**Figure 5: Model of the thesis structure (Dagberg, Thorén, Tozzi & Velichkov, 2013)**
Table 1: The time plan (Dagberg, Thorén, Tozzi & Velichkov, 2013)
2. Methodology

The following chapter is describing the method by which the present study was conducted. This part of the thesis is considering all the aspects of the scientific methodology, describing the scientific perspective and approach of the thesis, the research method, the data collection and finally the scientific credibility of the study. Each section of the chapter is also providing a motivation regarding the different methods which were selected.

2.1 Scientific perspective

In the field of scientific methodology, there are two main physiological paradigms which has been widely adopted in recent decades: positivism and hermeneutics (Åge, 2011). The following paragraphs provide an overall explanation of these two concepts, before defining which will be the scientific perspective adopted in the present thesis.

2.1.1 Positivism

According to the positivistic research paradigm, a concept gained popularity in the early 1800s and became the dominant paradigm for conducting research until the middle of the 20th century, knowledge can be considered as true only if it is created using the scientific method (McGregor & Murnane, 2010). Positivism as philosophy is based on the view that only phenomena which can be directly observed and measured are trustworthy from a scientific point of view, while, contrarily, things that cannot be scientifically detected are meaningless. Thus, according to positivists, only factual knowledge acquired by observation, including measurement, is reliable and consequently theoretical concepts are valid only if they can be quantified. Positivists argue that the purpose of the science is to help us to understand the nature of reality by attributing a specific empirical meaning to all theoretical concepts, since ambiguity cannot be tolerated (Ethridge, 2004). Following all the steps defined by the scientific method, people should feel comfortable taking the required actions, since conclusions stemming from the results of a scientific analysis can be trusted to be true (McGregor & Murnane, 2010).

2.1.2 Hermeneutics

The term hermeneutics comes from the Greek *hermeneuein*, which means “to explain, put in words” and refers to the interpretation of phenomena as signs. Interpretation is the act of understanding a phenomenon not only by observing the signs, but also by giving them a meaning. As a consequence, signs can be understood only if the individual utilizes its own assumptions to reconstruct and define the meaning of the sign itself (Marschan-Piekkari & Welch, 2004). This explains why hermeneutics is also defined as the philosophy of the interpretation of meaning (Butler, 1998). In this perspective, it is important to underline that individuals may understand in
a different way. As a result, following the hermeneutics approach, understanding is originated from the personal involvement of the researcher in a process of interpretation, that is strictly connected to the individual’s being-in-the-world (Dowling, 2004).

2.1.3 Scientific perspective of the thesis
The scientific perspective of the present thesis is positivistic since theoretical information and models were used as a basis to conduct a research focused on the inventory of the chosen company. Firstly, different theories related to the Inventory Management and the material handling processes within the stock were gathered and examined. Then this theoretical background was used to interpret the empirical data connected to the control of the company’s management over the inventory internal activities, with a particular attention to the order to delivery process.

2.2 Scientific approach
The validity of the final result of a research is generally founded on the researcher’s ability to adequately approach to the studied issue. In the scientific research, but also in our everyday life, we use two main approach in reasoning to draw conclusions on matters of importance, i.e. deduction and induction (Mantere & Ketokivi, 2013). A description of these concepts is provided below.

2.2.1 Deduction
Bara, et al. (2001) define deduction as a systematic process whose purpose is to draw a valid consequence from a series of hypothesis. According to the same authors, by following this scientific approach, researchers develop a series of hypothesis which are considered as true and subsequently build a theoretical structure on which the empirical data are verified in order to define which conclusion, if any, should be considered as the final result. As a consequence, with the deduction approach, researchers obtain a conclusion that must be considered as valid due to the fact that hypothesis are also considered as true (Bara, et al., 2001). It is important to note that hypothesis (on which empirical data are tested) are constructed as a logical observation of the reality, which makes deduction as an approach methodologically incontestable (Mantere & Ketokivi, 2013)
2.2.2 Induction
Induction is an empirical process by which conclusions are obtained from the observation of the reality, interpreted in terms of data or facts. Hypothesis and theories are therefore built on empirical data and not vice versa, as in the case of deduction. In this perspective, a research is seen as a process in which facts are observed to define the general rules to be followed in order to draw a conclusion (Ethridge, 2004). A similar explanation to this scientific approach is given by Lawson (2005). According to this author, using an inductive approach, scientists measures the different aspects of the phenomenon which is studied, and then those measurements are analysed to gain theoretical models needed to get the final result of the study.

2.2.3 Scientific approach of the thesis
In the present thesis empirical findings were collected from a series of interviews to company’s management, in which questions were formulated on the basis of the theoretical background previously constructed. Empirical data was therefore evaluated on the basis of the gathered models and notions. Existing theories were then used to comprehend and examine the outcomes of the interviews, in order to answer the research questions. On the basis of these considerations, the scientific approach used in the present thesis is deductive.

2.3 Research method
As described earlier, the study is based on a qualitative methodology with a deductive approach that deals with the relationship between theory and empirical data. According to Bryman & Bell (2011) following the deductive process, the researcher draws generalized conclusions based on observations, and with those he/she build a theoretical framework. Consequently, the research requires empirical investigation, and in this perspective it is important to determinate how data should be collected (Bryman & Bell, 2011). The decision and reflections about the relevant method approach to be used are strictly influenced by the way in which the empirical reality should be seen. While taking this decision it is also important to consider the type of information and knowledge the researcher will collect to conduct the study. There are various research approaches, depending on the research design and on what the study intends to lead to. The main approaches to assemble empirical data consist on considering the research as a wide study or a case study. The term “wide study” means that the researcher has many information sources to collect the data from, with the purpose to generalize the study. In a “case study”, the survey is limited to a specific information source, and the purpose is to examine the current status quo or to explain different connections between data (Johansson, 1993).
2.3.1 Research method of the thesis
To conduct the present study, empirical data was collected from a single source of information, i.e. IV Produkt, so it is possible to state that the thesis is focusing on a case study. The choice of this research method is also motivated by Johansson (1993), since the aim is to provide the company with proposals on how to improve the order to delivery process of raw material within the assembly area.

2.4 Data collection
Research data can be classified as either primary or secondary and the difference is explained in how the data is collected. The primary data is all material that has been collected by the researcher for example via interviews, observations or questionnaires to be used in the specific study (Björklund & Paulsson, 2003; Bryman & Bell, 2011).

Bringing the attention firstly to interviews, there are several interview types such as structured, semi-structured and unstructured interviews which the researcher must take into consideration during the decision of which type to be used for data collection (Bryman & Bell, 2011). The choice should be based on whether the study is a quantitative or a qualitative research. Bryman & Bell (2011) argue that there are usually significant differences between a qualitative interview and interview conducted in quantitative research. The approach tends to be much less structured in a qualitative research generating a higher flexibility for the interviewer in terms of the allowance to depart from any schedule or question guide prepared for the interview. The person can also ask new questions following the replies given by the interviewee. In quantitative research, none of these things should be done, because they will most likely compromise the standardization of the interview process and hence the reliability and validity of the measurement (Bryman & Bell, 2011). They continue to state that this point out general differences between qualitative and quantitative interview approaches, as a qualitative interview puts a much greater interest in the interviewee’s point of view; in quantitative research the interview reflects the researcher’s concern. In addition, researchers using the qualitative approach want rich, detailed answers while the quantitative approach is supposed to generate answers that can be coded and processed quickly. Furthermore, following the theory provided by Bryman & Bell (2011), semi-structured interviews are normally supported by some sort of an interview guide which is a list of questions related to a specific topic. The interviewee is given a large portion of flexibility in how to reply and new questions can be added during the interview, picking up details said by the interviewee. Questions outlined in the guide may not follow on exactly in the way they are given, but in overall, all questions should be asked and more or less the same wording should be used.
from interviewee to interviewee. The last interview type, the unstructured approach, has a character of a conversation as the interviewer may introduce just one overall question or topic to be discussed and the interviewee is then allowed to respond freely upon own ideas and interests. Therefore, interview guides cannot be designed for this last type (Bryman & Bell, 2011; Björklund & Paulsson, 2003).

Observations, together with qualitative interviews are probably the two most preferable methods when it comes to data collection in qualitative research (Bryman & Bell, 2011). This is linked to the reason that most of the activities connected with the daily life involve different form of collaboration among people. Observation is, according to Cuijpers, et al., (2006), a way to recognize how the theory actually works in the real life. Different alternatives of observation methods are available in order to collect data. Participating observation is one alternative in which the researcher just observes the activity either with the observed objects knowledge or with some sort of confidentiality. Observations can be conducted in several different ways and therefore it might be difficult to highlight typically strength and weaknesses for this specific method. The technique is well known as a time consuming method but can retrieve more objective information (Björklund & Paulsson, 2003). Since humans are able to understand the actions of other people because they possess a common sense of human behaviour, the observer simulates what the other is doing by using her/his own observation (Cuijpers, et al., 2006).

Bryman & Bell (2011) argue that the participant observer is taking a position in terms of seeing through others’ eyes as the observer is in a close contact with people for a longer time, and is participating in the same activities as the members of the social setting being studied. Such observation approach seems to enable the researcher to see what the other see.

According to Björklund & Paulsson (2003), by using questionnaires, a larger amount of primary data can be collected with less working efforts via standardized questions sent to the respondents. Bryman & Bell (2011) are describing self-completion questionnaires, where the respondents answer questions by completing the survey by themselves. This method is very similar to structured interviews, but the difference between them is that there is not the presence of an interviewer asking questions during the execution of the self-completion questionnaire (Bryman & Bell, 2011). There are many advantages and disadvantages connected to the use of questionnaires, and also many pitfalls are important to be clarified before the questionnaire should be developed in order to create appropriate surveys which carry out the necessary information (Hansagi & Allebeck, 1998). It is common to divide the survey into two types: mail
surveys and group surveys. The choice of which one to use depends on the purpose of the study, which is commonly missed by the researchers. The mail surveys is used if the study needs few critical information but from a high number of respondents, and it is therefore recommended to be used when the researcher wants to get an understanding of attitudes or standpoints of a high population for a specific phenomenon. This kind of survey should be developed and designed with short and concisely questions in order to increase the possibility to gain answers from the responses. The group surveys is instead used when the study is needed to have specific and detailed information from a low number of respondents, since just a few number of people can give the researcher right and appropriate information. To gain this detailed information this survey should be developed with more deeper questions. Consequently, to be able to know which of those two surveys the researcher should use, it is needed to clarify which sort of population will be studied, i.e. who are the respondents, and how many answers are needed (Trost, 2012).

The next step is to design the questionnaire, which should be seen as a practical tool used to measure the theoretical concepts. In this phase it’s important for the researcher to focus on what kind of information he/she wants to gain from the survey in order to formulate appropriate questions which should result in useful answers. The same question can be developed in many different ways, but what it is important is that the language is understandable so every respondent interpret the question similarly, in order to avoid misunderstanding. The questions in the survey could be formulated as open questions where the answer is designed in a way that the respondent can express himself in its own words. Nevertheless, another option is also to have questions with already developed alternatives of answer which the respondent fills in choosing the one that address to be the most correct from his/her point of view. In this way, the development of surveys should consist on both formulate appropriate questions and alternative ways to give answer to the question (Jacobsen, 2009).

To be able to formulate appropriate questions and define answers alternatives, Jacobsen (2009) recommends to follow 7 memory rules: (1) Make effort to formulate simple questions and avoid dual issues in the same question, since it creates confusion for the respondent; (2) Clarify the concepts used in the question to minimize the risk that a same term may be perceived differently by respondents; (3) People do not remember very far back in time, which is important to consider in order to narrow the temporal time to be examined; (4) Try to avoid leading questions, due to the fact that the respondent's own voice disappears and make the question irrelevant; (5) The response alternatives should carefully consider the use of middle classes or “I don’t know”-
category, since in these ways the respondent would be pushed to not put effort in thinking about the right answer; (6) Start the questionnaire with "harmless" questions and finish it with those questions which are more sensitive; (7) Vary the way in which questions are formulated to keep the respondent's attention and increase the answers credibility (Jacobsen, 2009).

According to Johansson (1993) and Björklund & Paulsson (2003), secondary data is represented by already written material presented in books, articles and brochures. Lots of authors have debated the use of secondary data, and they consider that it can give both advantages and disadvantages. The most problematic part by using such data is that the material may have been collected by a purpose different from the purpose of the present study, leading to a risk of an incomplete literature base. The researcher who intends to use secondary data is not familiar with the material or its quality, which can lead to misinterpretation (Johansson, 1993). This is important to have in mind when the researchers should use secondary data in order to minimize risk of misapprehension. One of the advantages of using secondary data is that it saves time and money for the researcher and provides the research a wider view of the area. A further advantage is that the secondary data is often of high quality as it has already gone through a selection process (Bryman & Bell, 2011).

2.4.1 Data collection approach of the thesis
Collection of primary data has been conducted via interviews and observations at IV Produkt. The interviews, in terms of face to face meetings, followed a semi-structured approach using question guidelines in order to let the respondents answer freely with the main object to gain as detailed data as possible. A few key observations, applied at the specific assembly line, was performed in order to provide the knowledge of the current internal order to deliver function, but also to measure and track the physical material handling within the area of study. The data generated from observations was combined with a shorter group survey, based on a combination of open questions and developed alternatives of answer, given to all employees working at the studied assembly line as well as within material supply functions in order to establish a clear and trustworthy picture of the real workflow process. The idea to have those two surveys was to let both the “customers” and “suppliers” with one voice express the daily work in terms of which activities are working and which are not, and which performance might create frustration. The questioner in the surveys was developed with help of Jacobsen (2009) memory rules in order to gain useful information. This was motivated by the fact that the timeframe given for the theses didn’t allow qualitative interviews with each and every employee involved in the study. The used
questioner is shown in the Appendix 1 and 2 later on. The employees in IV Produkt who have been participants in interviews or surveys are shown in Table 2.

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/ work task</th>
<th>Collecting method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leif Svensson</td>
<td>Production, HR &amp; Quality, Environmental Manager</td>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Patrik Johansson</td>
<td>Workshop Manager</td>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Andreas Johansson</td>
<td>Manager for Assembly line 2</td>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Mattias Kjellsson</td>
<td>Shop-floor Manager</td>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Björn Fredriksson</td>
<td>Sales Manager</td>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Operator Group 1</td>
<td>Working at Assembly line 2</td>
<td>Survey (7 respondents)</td>
</tr>
<tr>
<td>Operator Group 2</td>
<td>Working at the cutting area</td>
<td>Survey (2 respondents)</td>
</tr>
<tr>
<td>Operator Group 3</td>
<td>Working as forklift driver/ picker</td>
<td>Survey (6 respondents)</td>
</tr>
</tbody>
</table>

Table 3: Overview of the participated employees in IV Produkt

(Dagberg, Thorén, Tozzi & Velichkov, 2013)

Secondary data was collected in Linnaeus University’s library through the support of the university’s online database (http://lnu.se/the-university-library?l=en). In this way, it was possible to procure the material (textbooks and scientific articles) by which the theoretical background of the thesis was built. Online research was also conducted by the use of Google Scholar Database. Keywords used in order find information linked to the research topic were: Supply Chain Management, Inventory Management, Inventory Control, Work-in-process Inventory, material handling, Kanban, order to delivery process.

2.5 Scientific credibility

In order to make the study scientifically credible there are three important criteria to use according to Bryman & Bell (2011): reliability, replication and validity. The idea with the reliability concept is that it considers the question: if the research would be repeated, will the results be the same or will they be affected by random or temporary conditions? This criteria is therefore more recommended to be used in quantitative studies (Bryman & Bell, 2011). Considering the concept of replication, it measures if the study can or not be repeated. It can be seen as the extent to which it is possible to repeat the scientific research. If the researcher doesn’t illustrate in detail its approach, a replication is impossible to make. Replication is more adapted to use in a quantitative method, since in this case a specific structure/plan for each step of the work process is defined (Bryman & Bell, 2011). Finally, validity, which is one of the most
important research criteria according to Bryman & Bell (2011), has the purpose to assess if the conclusions generated from a research are linked or not to the study. To be more specific, validity measures if a concept truly reflects what the term is intended to represent. This measurement is divided into three different areas: internal validity, external validity and ecological validity. Internal validity concerns whether a conclusion that incorporate a causal relationship between two or more variables is sustainable or not. External validity is instead a form of validity linked to the question of whether or not the results of the study can be generalized within a specific research area. Ecological validity is focusing on the social area, which concern if the results are relevant in people's everyday live or in the natural social settings (Bryman & Bell, 2011).

2.5.1 Scientific credibility of the thesis
Reliability criteria was not considered in the present study due to the reasons that this thesis is a qualitative study, but also that the result has been affected by the business environment surrounding IV Produkt. Considering the replication concept, the present thesis was not illustrating a method which permits a future repetition of the study. Thus, also replication did not match with the purpose and the structure of this study. However, even if replication was not used as a guide method, the present thesis has described as detail as possible the methodology used to let the reader follow the logic behind the gained results. To make the study scientifically credible, the present thesis focused on the concept of validity which, together with a qualitative method, has permitted to properly analyse the raw data gathered from sources of information. In particular, by having an intense focus on the internal and ecological validity, it was possible to ensure a good agreement between the theoretical background and the analysis. The choice of such criteria is linked to the fact that the theory which has been developed in the thesis is based on the daily work at IV Produkt, therefore those two criteria’s have been important to ensure a common interpretation and understanding of the internal and ecological validity. Empirical data have been based on both surveys and observations to capture how IV Produkt works in the daily business. In this way, the assumptions of the causal relations between the different variables in the result have been based on reality which guarantees a high internal and ecological validity.
2.6 Ethical considerations
The concept of ethics plays a relevant role in the business university research. Ethics represents a controversial subject which researchers has to deal with so that they must be confident with the studied issues in order to avoid any criticisms on the chosen method of research and to guarantee that the results of the study will not be considered as tainted or even invalid. As a consequence, it is essential that the researcher clearly understand the ethical limitations which his/her community plays on the way the research is conducted and the final results are published. To ensure the ethicality of the own study, the research has therefore the task to make sure that no individual or institution has been harmed directly or indirectly by the spreading of the research finding (Remenyi, 1998).

2.6.1 Ethical considerations of the thesis
In order to ensure the respect of any ethical principle, during the first interview with Fredriksson, the Sales Manager of IV Produkt, a discussion was conducted to mutually agree on the confidentiality of the information and data which will be analysed in the present thesis and on the possibility to disclose/ make public the findings of the research.
3. Theory

This chapter provides a relevant theoretical background forming the basis for the following analysis. It is divided into three parts, each area describing specific academic topics and methods which are meant to be used in order to answer research questions, as visualized in Figure 6.

Firstly, a general description of the order to delivery process is provided. Such process is presented in the theory as composed by two main flows linked to each other: the material flow and the information flow. In order to answer RQ1, the first part of the chapter is also providing further information regarding different typologies of material flow management, as well as various activities of mapping out current material and immaterial flows.

Through the study of the current flows, weaknesses of the considered order to delivery process will be identified. That is the reason of introducing the second part of the theory chapter related to functions and tools used by companies to improve the current flows. In this context, a fundamental role is covered by lean and Six Sigma principles, implemented by tools as Kanban and by a development in the communication process.

The material flow is strictly influenced by the structure of the inventory. As a consequence, the third part of the theory chapter is providing inventory management solutions which a company may guarantee in order to satisfy the customer desires and manufacturing needs. A traditional approach is to classify the stored items into different classes or groups, before to implement a specific inventory policy. The policy described in such chapter is based on the ABC analysis.

Figure 6: Framework of the theory chapter (Dagberg, Thorén, Tozzi & Velichkov, 2013)
3.1 Order to delivery process
Due to the highly competitiveness on the market, the order to delivery process has become one of the most important process to manage within an organization (Forslund, et al., 2009; Okongwu, et al., 2012). The order to delivery is seen as a major source to gain competitive advantage, since a high focus on development and control of different activities inside the process often lead to improvements of the logistics performance and productivity, which make it possible to shorten the lead time, and consequently generate a higher service quality (Piroird & Dale, 1998). This process begins with an identification of a need to order and ends when the delivery of goods is made. In this way, the process starts with a series of activities connected to the receiving of material from suppliers, and it ends up with the logistics activities needed to make the product available and ready to be delivered to the customer on the right time. The order to delivery process may be initiated by a need to supply a warehouse, a direct need of material from a manufacturing order, or a need which has been generated by a received order. An ideal situation is when the customer order goes smoothly through all the activities within the process and the goods are delivered as promised, but in the reality operational disruptions might occurred and this may harm the possibility to deliver on the right time. Material shortage and quality defects, leading to stock-out situations, are just a few examples of negative consequences of such disruptions (Okongwu, et al., 2012).

3.1.1 Material and information flows within the order to delivery process
The order to delivery process is built around a physical and an immaterial stream, which are the material and information flow. Those flows should be linked to each other and the customer perspective should always be included (Liu & Liu, 2008). Customer service should be incorporated in each and every performance within the process, since all the activities related to the material flow should create added value for the customers. It is therefore important to avoid any ineffective activities, such as unnecessary movement of the material between different inventories, as they do not create any value which customers are willing to pay for (Jonsson, 2008).

According to Mattson (2011), the material flow can be briefly described as the movement of material that starts from raw materials and ends with the final delivery of goods to the consumer. Activities within the material flow are mainly about moving raw materials, semi-finished products and finished products from and to different types of inventories or stores. This flow goes in one direction, from supplier to customer, if we disregard returns related to eventual claims (Jonsson &
Mattsson, 2011). To be able to order material and deliver on time, information flow within a company must be synchronized with the material flow, and this means that the involved partners should constantly communicate with each other in order to guarantee an effective material flow (Mattsson, 1999).

Unlike the material stream, the information flow is based on two directions, where the supplier receives different types of information related to the customer’s demand and the customers require information from supplier in accordance with their needs (Mattsson, 1999). The information sharing is therefore an important key factor to gain effectiveness within a company, leading to an efficient physical material flow from the receipt of an order to the final delivery (Chibba & Rundquist, 2009).

From a customer point of view, the information flow in the order to delivery process starts by identifying the need of material, via the use of material planning systems or via direct requisitions (Mattsson, 1999). Via the use of such systems, organizations will be able to plan the quantity of material to cover their current and future needs. This information is submitted to a purchasing function with the task to send a purchasing order to the supplier. The purchasing order consists on a description of the company’s need, concerning the different types of products that are needed, the quantity, delivery time and other deliver requirements (Mattsson, 1999). Figure 7 visualizes the order information flows from customer to supplier.

![Diagram: Information flow of order from customer to supplier](image)

**Figure 7:** The information flow of order from customer to supplier (Mattsson, 1999, p. 204)
From the supplier’s perspective, the order to delivery process could be divided into three main sub processes, i.e. demand management, making and sourcing and logistics management. The demand management process consists on processing and confirming the order to the customers (Liu & Liu, 2008). Subsequently the order handling functions are started by the registration of the customer order (a “conversion” of the purchase order) into the IT system. The system reserves the material towards the order (Mattsson, 1999), which trigger the second sub-process of the order to delivery process, i.e. the making and sourcing. The latter initiates manufacturing activities, which include material planning, capacity planning, material purchasing, material outsourcing and production line efficiency. If the customer order is related to products which the supplier has in store, the order will be handled by a dispatch planning function that schedules and prepares the delivery. Finally, the order to delivery process ends with the third sub-process, which is the logistics management, consisting on handling those activities needed to make the product available and ready to be shipped, such as shipping inspection, package, combined delivery and transportation arrangement (Liu & Liu, 2008).

3.1.2 Push- and pull- based materials management
Who in the company is authorized to start the flow of material, meant in terms of order to delivery process? Answering this question it is possible to distinguish between two main material management approaches (see Figure 8). If production and the movement of material take place on the customer initiative, the material management is, in this case, of “pull type”. Material processes are therefore started up only when the consuming units place an order for them. On the contrary, if manufacturing processes or movement of material is initiated by the supplying units or by a central planning unit, the material management is of “push” type. In this case, material flow is initiated upstream the flow, by a centralized order or according specific plans (Jonsson, 2008). The push approach increases the probability of overlapping operations in the following steps of the flow, resulting in improved lead time performance, but on the other hand both material handling costs and transfer lot integrity may suffer in the process. Using the pull approach, reduces the number of transfers incurred in the flow and maintain a greater degree of integrity of physical lot of material, saving material for further uses (Kher, et al., 2000).

The material flow could be planned in a way of using contemporaneously the push and pull approach. For example, this is the case in which the customer demands material by using a re-order point method (an order is sent to replenish the material when the quantity in stock fall below a specific level) (Jonsson, 2008).
3.1.3 Flowcharts
A well-known method used by management and consultants to gain knowledge about the internal operating processes consists on mapping out current physical and immaterial flows. In this context, one of the most common tools used for such purpose is the flowchart, also called process map (De Feo & Barnard, 2004). This tool supports managers in identifying the flow of material and information in a process, by mapping the sequence of activities needed to carry out the process itself and providing an overall picture of the different steps required to accomplish a specific task. Flowchart helps not only managers but also the different parties involved in the process to understand it better and more objectively, with the aim to identify and eliminate obvious problems and deficiencies. The outcome of this tool is also more reliable if all the different categories of players involved in the process – employees, supervisors, managers and customers – participate together in the construction of the flowchart (Evans & Lindsay, 2005).

By integrating all the types of workers in the development of this chart, they can feel a sense of ownership, and therefore become more willing to improve the process. In addition, employees may better understand what is their position within a process and which are their suppliers and customers, and this will lead to relevant improvement in the communication within different areas within the company. To create a flowchart, managers should gather all different parties and work as a moderator, by guiding the discussion via questions such as: “What operation is performed at this point of the process?”, “Who makes the decision at this point?”, “What happen next?” and so on. Once the first flowchart is constructed, it will help managers to identify source of errors and defects and define where in the flow quality-related measurement should be taken, with the final purpose to pinpoint specific areas in the flow where it is possible to obtain improvements (Evans & Lindsay, 2002).

According to Gitlow et al. (1995), there are numerous and different typologies of flowcharts. Among those, the most commonly used are:
1. Process Flowchart

This chart appears like a pictorial summary of the sequence of operations and decisions that make up a process. It illustrates each phase of a process by using specific standard symbols, with the aim to get better clarity and readability. The shape and the information written within the symbols provide information regarding the specific step of the process (Gitlow, et al., 1995). Table 3 shows examples of symbols that could be used in a process flowchart describing the processes connected to the material flow of an ordinary manufacturing company.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Denomination</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operation</td>
<td>Modification or transformation of units at one workplace. Such operations may be carried out by machines and/or labor expenditure and does not necessarily add value to the final product</td>
<td>Assembly, disassembly, change of shape/size, machining etc.</td>
</tr>
<tr>
<td></td>
<td>Transport/Movement</td>
<td>Direction of the flow of material</td>
<td>Change in location of product from one workplace to another</td>
</tr>
<tr>
<td></td>
<td>Storing</td>
<td>Storage area</td>
<td>Store of raw material, semi-finished or finished products</td>
</tr>
<tr>
<td></td>
<td>Waiting time / Time delay</td>
<td>Delay and waiting of work in process</td>
<td>Queues, waiting lines etc.</td>
</tr>
<tr>
<td></td>
<td>Decision point</td>
<td>Comparison of the product with a standard of quantity or quality</td>
<td>Decision for acceptance or rejection of the item</td>
</tr>
</tbody>
</table>


Since there will be a hierarchy of actions for any process design, it is firstly necessary to define the relationships between the different elements of the process. Once the different parties and the relationships between them are defined, it is possible to follow three main approaches for developing the overall chart: top down, bottom up or a combination of those. In the first case, management starts from a macro level and then develops the flowchart in details for each of the elements, until the lowest hierarchic level of the process. On the contrary, the bottom up approach starts from the last level and then move upward until the highest stage of the process. Following
one or the other approach the result will be the same, i.e. the construction of a business interaction model providing a macro view of the process with respect to its suppliers, inputs, outputs and customers (Goel, et al., 2005). If the aim of the process mapping is to get a deeper knowledge regarding the flow of material within the company’s plant, the process flowchart will consist in this case on representing the process map describing material handling activities between different storage places, production activities, etc., from the earliest stage of the raw material procurement to the delivery of finished product to stock or directly to the customer. In this way, management will have the possibility to gather information about which item moves in which sub-flow, and which stock and transportation activities take place in the flow of material. Different sort of data is required to conduct this study (e.g. flow of each item per time period, average quantity in stock, value of the item in stock etc.), depending on the level of analysis which managers want to conduct (Jonsson, 2008). Figure 9 provides an example of the process flowchart in a classic manufacturing company.

2. Layout Flowchart

This flowchart represents the floor plan of an area within the company, highlighting the flow of paperwork or goods and the location of equipment, storage areas, file cabinets and etc. The purpose of this flowchart is to identify wastes resulting from an inefficient layout and identify areas for improvement to allow a more profitable utilization of the space (Gitlow, et al., 1995). This type of chart is therefore used when a more rational layout is needed, or when the current layout must be modified due to modifications in the production area (Jonsson, 2008). The layout flowchart illustrates, by the use of arrows/lines, the movement of material between the various operations within the area taken in consideration. All works sequences need to be identified and staffing level confirmed (Labach, 2010). An example of this tool is shown below in Figure 10.

Figure 9: Process flowchart (Chase, et al., 2006, p. 161) (Jonsson, 2008, p. 113)
Among the other process mapping charts, a tool that shows some similarities with the Layout Flowchart is the spaghetti diagram. The aim of this chart is to provide an overall view of the material flow in a process and show the wastes of transportation and motion that should be eliminated, driving the company towards a more lean orientation. Spaghetti diagram differs from a classic Layout flowchart since it analyses more in details the flow of material, by observing the frequency of operators’ movement while picking the required items within the inventory (Talip, et al., 2011). By following the operator’s movements drawing a line on the map of the studied area, it will be possible to highlight repetitive movements, as material may be placed on a number of different locations (Labach, 2010). Showing the movement of material from a “Goods In area” to a “Goods Out area”, will give management an idea of the complexity of the material flow within a specific plant. This explains the meaning of the name chosen for this diagram. The term “spaghetti” adequately describes the concept according to which flows that cannot easily be followed, cannot either easily be understood and efficiently implemented. Adopting an inefficient layout will increase this complexity, resulting in a higher cost and time to complete the process. Lead time and cycle time will rise up and the material will not flow in a flexible way, reducing
the productivity and the consequent profitability of the company. In order to face these deficiencies, a new spaghetti diagram must be drawn in a way to re-think the work process, ensuring a smoother flow of material than before (Talip, et al., 2011). Spaghetti diagram is therefore particularly advantageous in identifying how to change the layout of an area to minimize walking and other non-value activities (Labach, 2010). Figure 11 illustrates an example of spaghetti diagram implemented in a printing company.

![Figure 11: Layout plant for a printing company before (A) and after (B) a Spaghetti diagram analysis (Allen, 2010, p. 130)](image)

**3.2 Function and tools to improve the order to delivery process**

Management needs to have knowledge about the material structure of a product, technologies used, production itineraries and the physical size of the storage, since this is necessary information for scheduling material needs and the physical inventory layout, in order to understand the demand on how much of each item is required in a specific period. It is important for a company to efficiently plan and control the material flow, since, as described before, it may influence several areas within the company, such as sourcing and procurement, transport and warehousing processes, inventory, working capital and the cash flow (Śliwczyński & Koliński, 2012). Material management is only focusing on the material flow, and is used to determine quantities and time points for all items in the manufacturing and purchasing orders (Seong & Soo,
Ren et al (2011) explain that this management is used to plan and control all the necessary efforts to ensure that the quality and quantity of materials and installed equipment are available when needed and in a reasonable cost. Therefore, the goal of management consists on achieving an efficient material flow with respect to the tied-up-capital. In order to reach this goal, companies’ materials management should be able to answer four different questions: “(1) For which items must new orders be planned (item question)? (2) What quantity must be stated in the order for each item (quantity question)? (3) When must the order for each item be delivered to stock, directly to production or directly to the customer (delivery time question)? (4) When must the order for each item be transferred to the supplier, or when must it be initiated in internal production (start time question)?” (Jonsson, 2008, pp. 263-264).

3.2.1 Lean and Six Sigma principles
From a material management point of view, the most critical aspect is to supply every chain member with the right amount of material on the right time so the entire process is not interrupted. In this way, one of the main objects for the material management is to maintain a proper level of inventory, supporting a continuous production activity. A proper inventory level, by maintaining such level between a determined safety stock level to a maximum stock yard capacity, represents the main solution for a company to avoid stock-out and yard overflow (Seong & Soo, 2011). According to Breyfogle, et al, (2001), there are today two main approaches supporting management to reach efficiency in the material flow: lean manufacturing and Six Sigma.

The lean concept, as in lean manufacturing, lean production, etc. represents one of the most innovative and widespread approach used by process-based firms to support management in removing different kinds of waste within company’s internal environment, through a continuous improvement (Andersson, et al., 2006). Concepts as “lean” and “waste”, primarily adopted in the production operations of Toyota in the early 1950s, has become nowadays fundamental principles in the quality improvement activity of every manufacturing company (Dahlgaard & Dahlgaard-Park, 2006). Serrano et al. (2009) describe the lean philosophy as founded on the minimization of the resources used within the internal processes of an organization. The purpose is to identify and eliminate all those activities in design, production and supply chain management-related processes which do not add value from the customer’s point of view, i.e. activities which the buyer is not willing to pay for. Organizing the production as a “lean” allows firms not only to be more responsive to the rapid changes of market demand, but also to show a higher customer
orientation (Seth & Gupta, 2005). According to Andersson et al. (2006), the lean principles, which are primarily customer value driven, can be summarized as follow:

1) *Understanding customer value*: considering the product/service provided, what customer perceive as value and is willing to pay for;

2) *Value stream analysis*: managers have to revise the internal business processes and determine which ones actually add or do not add value for the customer. The purpose is to eliminate those actions/processes which the buyer is not willing to pay for;

3) *Flow*: the aim is to re-organize production activities or other supply chain processes in order to get a new continuous flow;

4) *Pull*: the flow is now organized in a way that customers pull finished products through the system; in other words, work is not carried out without a requirement from downstream;

5) *Perfection*: the removal of waste (non-value-adding activities) is a continuous process, since there is no end in reducing wastes in time, cost, space, mistakes and effort.

Likewise lean conception, Six Sigma can also be considered as a new holistic and multidimensional business improvement approach which aim is to increase both customer satisfaction and the company’s financial health, as explained by Breyfogle, et al. (2001). The authors explain that this method substantially consists on a series of interventions and statistical tools which support management in gaining breakthrough profitability and relevant improvement in terms of operations quality. In details, Six Sigma is built on a set of tools used by managers to get knowledge about the quality level of the output of each internal process, in order to limit the overall variability of the output within specific limits. That explains why this approach is called with the Greek letter Sigma (σ), a symbol used within mathematical disciplines to indicate the standard deviation (i.e. a measure of the variation about the process average) (Breyfogle, et al., 2001). Six Sigma is therefore built on a problem solving methodology, involving a wide range of statistical process improvement tools. If it is conveniently used, it allows companies to eliminate causes of defects and errors by decreasing cycle time and cost of operations, improving productivity, better meeting customer expectations and leading to a higher asset utilization and return on investment (Evans & Lindsay, 2005).

As noted by George (2003), both Lean and Six Sigma methods show specific deficiencies and lacks. The author explains in general terms that Lean fails in addressing key concepts like customer needs and variation by not bringing a process under statistical control. On the other hand, Six Sigma cannot lead to relevant improvement in process speed or in capital reduction,
since it has a limited focus on anything related to quickness and flow. These arguments are frequently used by academic researchers to address the choice of one method over the other, rather than supporting the solution to see both methods as complementary. As a consequence, George (2003) proposes the adoption of a fusion between Lean and Six Sigma, an idea which is also supported by more recent literature (e.g. Atmaca & Girenes, 2013), according to which these methods can work successfully together.

3.2.2 Kanban
One of the main methods used by companies aiming to implement lean and six sigma principles is Kanban (Dahlgaard & Dahlgaard-Park, 2006). According to Juniora & Filhob (2010), Kanban can be defined as a material flow control mechanism implemented by companies to control the proper quantity and proper time of the production of necessary products. This system represents one of the most common solutions adopted by companies working with a pull-based material management (Rishnamurthy, et al., 2004). Kanban was firstly implemented in the early 1950s in the Toyota production system with the aim to implement the concept of lean production by orienting the manufacturing processes toward the principles of JIT (Just-in-Time) (Gross & Mcinnis, 2003). The idea of JIT is based on the elimination of all sources producing waste, by getting the right quantity of raw materials and manufacturing the right quantity of products in the right place and on the right time. In this context, Kanban system represents one of the simplest, most effective and inexpensive process management tool to implement the principles of JIT within a company’s production and inventory, as explained by Mukhopadhyay & Shanker (2005). Kanban strategy is aiming companies to reach different objects, such as decreasing the amount of material in stocks, improving the handling process of goods, decreasing cycle times as well as the amount of managed information and removing any form of wastes within the treated process (Juniora & Filhob, 2010). In this way it will be possible to improve the quality of services provided and this explains why Kanban has become today a “survival strategy” for many firms (Mukhopadhyay & Shanker, 2005).

The term Kanban literally stands for “card signal” (Mukhopadhyay & Shanker, 2005). The meaning is explained by Kumar & Panneerselvam (2007) considering the fact that this system is based on the use of plastic cards used to control the entire flow of the manufacturing and inventory processes. Each single card contains all the information required for the assembly/production steps of a product at each stage of the process. The authors also explain that it is possible to use either a single-card system or two-card system. Cards are denominated with a
specific number to identify the production step of a specific product, in order to control the whole work-in-process levels in the enterprise (Spearman, et al., 1990).

A single-card Kanban system is visualized in Figure 12, based on two stages (A and B) connected with each other via two closed loops and a stock point in-between. Each stage contains of a work center and an area for holding inventory. The idea is that all production and inventory is kept in standard containers or boxes having equal number of items. When work center B has consumed a box and require more material to work on, it puts the move Kanban in the holding box and forward the empty container to the work center A. The empty box arrived in center A is seen as the trigger to produce new material equal to a standard box. The move Kanban is taken from the holding box and transferred to the output stock in stage A. This gives the permission for collection of a full container to be moved from output stock A to working center B, and by that closing the two loops (Slack, et al., 2004).

![Figure 12: The operation of the single-card Kanban system of pull control (Slack, et al., 2004, p. 534)'](image)

The method is also explained by Jonsson (2008) regarding transfer of material between stocks to supply assembly activities and can be seen as a single-card conveyance Kanban defined by Slack, et al (2004). The Kanban principle explained in Figure 13 is built up on four steps. The assembly area makes a withdrawal from the local store. The Kanban card attached in the new pallet is then removed and forward to the central store. This action is equal to the movement of Kanban.
between stage B and output stock A in Figure 12. The empty card received by the central store initiate a replenishment flow of one pallet, from the central store to the local store in accordance with instructions on the card. The card is attached to the new pallet at the central store before it’s moved to the local store where it will be kept until moved to the assembly line, closing the full loop (Jonsson, 2008).

Figure 13: Use of Kanban card for transfer between stocks (Jonsson, 2008, p. 275)

The explained pull method is a straight forward and transparent system aiming for material movement only when it’s needed, which gain positive effects in terms of limiting the inventory which accumulates between stages. The number of Kanbans used within the loop should be equal to the number of containers or boxes, also representing the inventory carrier within the system. By reducing the number of Kanbans by one equals a reduction of boxes by one and consequently the inventory (Jonsson, 2008).

3.2.3 Information and communication system
As described before, an efficient material flow must be supported by a well implemented information flow. Within the order to delivery process the information is mainly based on several different technical systems which the operators transfer information to. This information should with the help of the system be communicated out to the other company’s members in the different departments (Okongwu, et al., 2012). Today, due to the tendency among companies to work in
network structures, internal and external communication issues are more and more complex, and this has led to the need of a well-developed communication process (Lascu, 2011). Having a well suppurated information flow is important for the material handling, but according to Chibba & Rundquist (2009) it is not effective to focus only on an integrated and well-developed information system. According to the authors, it is also fundamental that the employees have a clear understanding on how and why they should use the information system in the daily work, and on how added value for the customer can be generated via the use of the system. The best way to communicate new knowledge and information to the staff is mainly by mouth to mouth, rather than with help of a system. Due to that, it is important to have an interface between the paper system and the database, and between the old and the new information storage culture in order to make the information flow effective between departments (Chibba & Rundquist, 2009). For that reason, internal communication has become more and more important for the firms, so the staff can get right information on time to be able to deliver the customer order as planned (Lascu, 2011). The internal communication system is built on three key fundaments: hierarchical communication (the information-sharing in vertically structure, from the top to down, and vice versa), media communication (sharing information via email, the firm’s internal website, newsletters, meeting, etc.) and informal communication (spontaneous information-sharing via corridor discussions, during the lunch or coffee breaks), and in order to spread the information through the whole organization these three have to be interdependent on each other (Falkheimer & Heide, 2007). The company’s management needs to have an understanding about the communication system within the firm and how it is influenced by the human behaviours and human relations, in order to create a high degree of harmony, which is the key to actual communication. The ability to create an efficient communication flow is built on trust which means that the employees have trust in the persons who communicate which also gradually affect the degree of harmony. In order to create harmony in the communication process the manager can divide the process into four stages, “perceptive faculty”, “expressing the feelings”, “own needs” and “expressing a certain need by request”. These four steps should be consider in order to: (1) define actions which start the communication, (2) understand the object in it, (3) identify the actual needs and (4) express the wishes and requests in a certain way so as to reach the defined goals. By having an interpersonal communication within the company marked by empathy through every stage of the process, it will result in a well-developed communication and understanding of the objects of different partners, whether inside or outside the company. By having a well-developed communication process inside the company, will optimize the firm’s specific information system and consequently improve the material flow (Lascu, 2011).
3.3 Inventory management to support material supply
There is often a waiting time from when the order is placed to the moment in which the request is satisfied. From an inventory point of view, this time window is defined as “replenishment lead time” and it may be generated by an ordering time-delay or a production/distribution delay. The material flow is based on the structure of the inventory, so it is essential that managers have an adequate knowledge on how to design and implement an inventory replenishment policy, since it will directly affect the financial and material flow (Garcia, et al., 2012). An inefficient management of the material flow at a level of inventory could lead to relevant negative consequences for the economy and effectiveness of the company (Ballou, 1987). Due to that, Mercado (2008) explains that companies require an efficient inventory management to deal with different issues regarding warehousing, in order to give managers the necessary instruments to take decisions on how much to keep in store and how much and how frequently to re-order. The purpose of inventory management is to meet customer demands while keeping inventory cost at a reasonable level in order to maximize the profitability of the company. Having a high focus on reducing inventory cost and meeting customer demand are two objects which are clearly opposite to each other (Mercado, 2008). Keeping raw materials, components and finished products in stock consumes space and tie up capital that cannot be invested in other alternative ways. On the other hand, by keeping a high inventory level, gives the company a short response time to deliver the product in accordance with the customer request (Lambert & Stock, 1993). Consequently, one of the main issues in the field of inventory management is to create a balance between inventory level and customer service performance (Mercado, 2008). The challenge for the company’s management is therefore to control activities over the inventory to respect financial targets and, at the same time, to supply the needed quantity and quality of products to meet both customer’s requirements and manufacturing needs (Lambert & Stock, 1993).

Improvements in this area can be reached by developing and implementing specific strategies connected to the inventory management, such as timely supply, quantity discount, buyback/return policies, quantity flexibility etc. (Sana, 2012). The adoption of a suitable inventory strategy is also required by the fact that the stock level in the different activities in the order to delivery process is often inaccurate. Inventory inaccuracy incurs when the stock level shown in the information system is not in line with the actual level of inventory (Rekik, 2011). Management is therefore needed to adopt an appropriate model of inventory control with the aim to optimize the chosen inventory strategy (Hai, et al., 2011). An appropriate inventory service level, a high delivery reliability, a certain accuracy of the quantity and quality of ordered products are only
few examples of the different inventory performances that a company may guarantee in order to satisfy the customer requirements and desires (Kisperska-Moron, 1996). A suitable inventory strategy is also necessary to face the different instabilities arisen at both the upstream level (supply system) and downstream level (customer demand fluctuation) of the chain. One principal way to face these instabilities and, in general, to mitigate supply risks is to improve confidence among responsibility areas within the inventory, through collaboration and a better information sharing (Bendre & Nielsen, 2013). Collaboration is based on a continuous exchange of capabilities and knowledge with the aim to integrate this information within the flow of material/product and information across the process (Chan & Prakash, 2012).

3.3.1 Classification of items within the inventory
The ability to have an efficient control over the large number of inventory items has become an important aspect within the field of inventory management, and the classification of items is extremely important to manufacturing logistics and industrial companies. A categorization of items will support the stock management in the decision making process, but can also be seen as a help in the identification of potentials. In addition, a classification of items can assist determining the material planning strategy of different items (Scholz-Reiter, et al., 2012). Companies, even with moderate size, often have thousands of stock keeping units (SKUs). The term SKU refer to products to be kept in stock and are completely specific as to function, style, color, size but also physical location. Policies, related to production and inventory, are influenced by the characteristics of the product. Features such as product volume, product value, annual sales volume and predictability of demand or storage requirements can affect, in different ways, such policies (van Kampen, et al., 2012).

A traditional approach is to classify the inventory or SKUs into different classes or groups, in order to facilitate the implementation of different inventory policy to individual groups (Ng, 2007). This can be done by placing items with are dependent on each other, i.e. which have similar handling or transportation requirements, in the same zone of the inventory. By doing so, if most of the picking orders refers to items belonging to the same group, it will be convenient to place such articles in the same area within the storage in order to decrease handling costs and movement of material. On the contrary, picking orders which include articles of different categories require more transportation and handling work since pickers are required to move in different zones of the inventory (Jonsson, 2008).
3.3.2 ABC analysis

Two simple questions need to be answered when to create a classification of items within the inventory: how many classes are used and how are the borders determined between the classes (Ng, 2007). A well-known and commonly used classification practice is the ABC analysis which is based on the Pareto principle (Ng, 2007) and visualized in Figure 14. The method aims for dividing the inventory into three classifications (A-C items) and should be seen as a way to separate the “important” from the “unimportant” (Heizer & Render, 2004). The principle states, based on annual demand per item times the cost per unit (in dollar), that class A items represents those items with a high currency volume (approximately 80% of the total dollar usage), but represent at the same time a lower number of the total inventory items (approximately 20% of the total inventory items). Class B items represent approximately 30% of inventory items and 15% of the total value. Finally, the C items representing only approximately 5% of the dollar volume, but about 50% of the total inventory items (Heizer & Render, 2004).

![Figure 14: ABC analysis based on the Pareto principle (Heizer & Render, 2004).](image)

The ABC analysis can be conducted by management with the aim to identify the specific inventory strategy to be implemented, taking as basis for calculation the picking frequency of
items. The idea behind such analysis is to minimize the material movement and handling work required for those categories of products which are picked most frequently. A main solution to implement such strategy is to locate such articles in the most accessible spaces in the inventory (Jonsson, 2008). The ABC approach is also used to classifies product groups on the basis of demand value or demand volume (van Kampen, et al., 2012), or ranking the items according to the annual turnover (Scholz-Reiter, et al., 2012). The analysis method is easy-to-use and simple-to-understand, but the traditional ABC is based only on single measurement, such as the previously mentioned annual turnover. According to van Kampen, et al.(2012), such approach normally multiplies the demand volume by the unit price and then the single criterion is sorted based on the demand value. This has led to the recognition that other criteria such as inventory cost, lead time, part criticality, commonality, obsolescence, number of requests per year, order size requirement, demand distribution, durability, substitutability and so forth, are also important in inventory classification (Ng, 2007). One way to add an extra dimension to the traditional approach is to introduce a XYZ analysis generating an ABC-XYZ analysis. The XYZ analysis can for example handle the usage regularity of a product or in other terms their fluctuation in consumption. ABC-XYZ classes can be set as follow (Scholz-Reiter, et al., 2012, p. 1):

- **A-items:** 0-80 percent of the accumulated consumption value
- **B-items:** 80-95 percent of the accumulated consumption value
- **C-items:** 95-100 percent of the accumulated consumption value
- **X:** some extent constant consumption, fluctuations are rather rate.
- **Y:** stronger fluctuations in consumption, usually for trend-moderate or seasonal reasons.
- **Z:** completely irregular consumption.

By applying such combined analysis, a classification matrix (AX, BX, CX, AY, BY, CY AZ, BZ, CZ) can be obtained, giving the advantage to combine items having similar characteristics and by that process them with the same material planning parameters (Scholz-Reiter, et al., 2012). A similarity and relationship perspective is important to keep in mind and should be considered by the management as classifying individual products ignores possible relationships between products. The possibility to deliver to a customer might be dependent on whether all products on an order are available or not. From a production point of view, products can be clustered on receipt or packaging format in order to reduce set-up cost, which in turn might have an important influence while designing a SKU classification system for inventory management (van Kampen, et al., 2012). Following the result presented by van Kampen, et al., (2012), there are several
reasons for classifying SKUs and such work is mostly conducted in the field of inventory management with the aim to determine order/production quantities, reorder points and safety stock for different SKU groups. It was also found, by the authors that product classification could be used to choose between different distribution channels, including customer prioritization and make-to-order or make-to-stock decisions, but also while defining the most appropriate supply chain for a product, mainly based on demand predictability.

3.3.3 Physical layout of storage
Unnecessary movements of products and materials can be avoided by adjusting the layout of the store to the processes carried out within. This could be done by localizing and distinguishing high-frequency and low-frequency items with the aim to eliminate different kinds of waste linked to unneeded transportation of material. Minimizing the physical transport distance can lead to decreasing cost of material handling within the stores, but at the same time the company also has to carefully consider that the physical layout of storage must be structured in a way to get efficiency in material picking activities (Jonsson, 2008).

According to Jonsson (2008), the purpose while designing the layout of a store, is to generate a rational distribution of the items, in accordance with their rate of utilization. On the base of this consideration, the author suggests two main structure layouts of stores: Linear layout and the U-shaped layout. If the first type is used, all the goods and raw materials will be transported approximately at the same distance, since goods reception and outbound loading will be located in opposite side of the store. On the contrary, adopting the second type of design, the materials reception and outbound loading are in the same side of the plant. De Koster et al., (2007) describe different other kinds of storage layout options such as random storage, closest open, full turnover storage, class based storage, location storage, dedicated storage etc. Such designs of warehouse are analysed in combination with order picking activities, linked with the process of retrieving materials and goods from the storages, in order to satisfy the assembly/manufacturing needs or a specific customer request. Chen et al., (2010) explain that the order picking processes have a relevant influence on the responsiveness of warehouse management. According to Brynzer & Johansson (1996), firms should adopt an order picking system which allows an efficient handling of material, respecting their size, weight and frequency. Policies used to control the picking systems may include storage policies, order batching and picker routings (Chen, et al., 2010).

Nowadays one of the most common storage policy used by companies to manage their warehouse layout is represented by the Class-based method, widely used in practice because of the ease to
maintain and implement. The aim of this policy is to implement an ABC analysis to improve the throughput of inventory operations, by positioning material within the store in accordance with the demand frequency (Chen, et al., 2010) (de Koster, et al., 2007) (Caron, et al., 2000).

By using this method, items are divided in three classes: A, B and C. The A class is connected with the fastest moving components, the B class is linked with next fastest moving items and the C class is connected with the rest (Chen et al., 2010). The logic behind this classification is that the selected classes of products mirroring the frequency of moving material within the warehouse, in a way that the A class items represent 80% of the most frequently ordered and 20% of the shelf space, while B class amount to 50% of the items covering 30% of the shelf space, and so forth. Each class area can be located in the store following different guidelines. As an example, Figure 15 shows different cases of a Class-based storage, where items with the highest frequency are located to the aisles closest to the workshops. In particular, Figure 15 (A) visualizes a multiple configuration of classes distributed across aisles, while Figure 15 (B) illustrates a case in which storage aisles are connected to only one class and finally in Figure 15 (C) represents a "within-aisle storage", where the input/output point is located centrally in the storage. The choice between one and the other storage layout is influenced by different elements: the routing policy that pickers use, prevention of congestion, the presence of simultaneous replenishing processes, etc. (Chen, et al., 2010) (de Koster, et al., 2007).

![Figure 15: Examples of different storage layout using a Class-based method (Chen, et al., 2010, p. 72; de Koster, et al., 2007, p. 490)](image)

Using the Class-based method, items with the highest picking frequency are assigned to the aisles nearest to the inventory input/output point. In other words, high-frequency items (A class) will be stored close to the assembly lines/production area, while such distance will increase progressively for the following classes. Several benefits are connected to the use of this storage layout policy,
among which: 1) the possibility to cut time in carry out picking activities, resulting in a faster flow of material within the inventory; 2) reduction of the expected number of “visited” aisles in a picking order tour (more than one items are picked together); 3) minimization of the distance which operators have to cover to reach the requested items, resulting in saving costs and time in warehouse operations (Caron, et al., 2000).

Regarding the last point, the travel distance is often consider as a primary focus when the managers develop the layout of the warehouse and it can be divided into two types: the average travel distance of a picking tour (average tour length) and the total travel distance. By having divided the travel distance into two types should facilitate managers to develop an appropriate warehouse design. The aim is to develop an efficient picking process, resulting in a decrease of the total cost (both in investment and operation cost) and also in a minimization of the overall throughput time (de Koster, et al., 2007).

To efficiently apply this method, the statistical relationship between different components (e.g. the frequency at which they appear together in different orders) should be known or predictable. Order and stocking data have to be adequately processed to assign items to each specific class and that is the reason why the class-based method is generally used within companies which use an information intensive approach while managing inventory operations (de Koster, et al., 2007).
4. Empirical data

This chapter is providing empirical information and data which will be further on combined with the theory to construct the following analytical part of the thesis.

The chapter is firstly providing a general description of the overall order to delivery process within the company, highlighting the related sequence of activities. The process and the material flow taking place within company’s plant are then visualized in maps.

Moreover, a deeper description, through specific measurements, of the studied process area is provided. The collection of data regarding the studied order to delivery process from material supply functions to Assembly line 2 is conducted considering the components forming the specific modules/units which are the most frequently produced within the considered assembly line. In particular, three main material flows are highlighted. The comprehension of the studied order to delivery process is supported by different kind of flowcharts and by the collection of data related to the picking frequency of the identified components. The knowledge about the daily material and information flows is further on extended by showing the results coming from the questionnaires, filled in by the operators involved in the study.

4.1 Mapping of the entire order to delivery process

The whole order to delivery process taking place in IV Produkt’s plant, from the identification of the customer needs to the delivery of the finished product, is described below and subsequently visualized by Figure 16. This paragraph gives a general explanation of the current operations taking place within the company, while a deeper description of the area of study, i.e. the circumscribed order to delivery process from supply functions to AL2, will be provided in paragraph 4.3.

4.1.1 Sequence of activities within the process

1. Customer demand

1a) The customers discuss, together with IV Produkt’s salesmen (Sweden) or agents (abroad), their current needs.
1b) This information is gathered within the forecast planning database, within the IFS system.
1c) When the seller and the customer agree upon the total project and time schedule for the required product, the customer places an order via mail/fax to the master planning department.

2. Master planning

2a) Master planners receive the customer order.
2b) Personnel within the department enter the order into IFS and book the delivery date.
2c) Master planners confirm the customer order to sales department, which in turn confirm it to the customer.

2d) Master planners make a general plan over the production, and send this information via IFS to the different manufacturing departments (panels, fans, assembly lines, aluminium profiles). The system also counts down backwards to give the information about when the production of each specific component is needed to start, in order to be able to deliver the order on time.

2e) The personnel plans and processes the required material and send the purchase demand for the items that are not in stock.

3. Purchasing

3a) Purchasing department receives material requirements.

3b) A procurement plan for the required quantity of material is defined.

3c) Purchase orders are processed and sent to suppliers.

4. Suppliers

4a) Suppliers receive the order from the Purchasing department and confirm it.

4b) The Purchase department communicates with suppliers in order to assure that activities are carried out as planned.

4c) Suppliers procure the material and delivery it to the good reception.

5. Goods reception

5a) Goods reception department receive material from suppliers.

5b) Personnel unload, scan and check the quality of material.

5c) Material is place in store.

6. Production

6a) Production departments (panels, fans, assembly lines) receive production orders from the master planning. The personnel at the production offices sort those received orders and make a deeper production plan, which is focus on:

- Shop floor planning based on product structure, to ensure that sub-processes start correctly in order to deliver the needed components on time;

- The capacity of all the working hours they have authorized for the week.

Through such plan, weekly working lists for each production department are structured.

6b) Those lists are printed out and delivered to staff at production departments. All operators follow their own list in the daily work, with a “top-down” approach.
6c) Forklift drivers/pickers collect material from external and internal warehouses/storage areas and move it to the different production departments and assembly lines.
6d) Workers at assembly line follow the list of all manufacturing orders which should be carried out during the week and produce them one after one. Assemblers pick material from the storage facilities within the line and bring them to the assembly table.
6e) Finished physical products are delivered to the packaging area and a production order in paper format is placed in the finished customer order map and registered into IFS as “closed”.
6f) This map is picked up 4 to 8 times per day and delivers to the master planners.

7. Packaging
   7a) Packaging department receive finished physical products.
   7b) Operators pack the product and delivery it to a loading bay, waiting for transportation to the customer.
   7c) The final load is carried out by the packing operators on the loading day and by the fact the order is delivered to the customer.

8. Master planning
   8a) Master planners receive the map of produced and finished customer orders.
   8b) Personnel book transportation and give delivery confirmation to the customer.
   8c) Master planners register the order into IFS as finished and communicate that to the Finance department.

9. Finance department
   9a) Finance department receives communication about the finished order.
   9b) Personnel print out the invoice and send it to the customer.
Figure 16: Mapping of the entire order to delivery process (Dagberg, Thorén, Tozzi & Velichkov, 2013)
4.2 Material Flow
The map illustrated in Figure 17 represents a layout flowchart by illustrating, on the plant map, both the sequence of operations that makes up the internal processes and the current flow of material, with a focus on the studied assembly line.

As it is possible to note by the chart, the inbound flow starts with the reception of goods (1), which are sorted and scanned into the data system (IFS) used by the company. The received material is further inspected and controlled in a test/control area (2), in order to ensure that the delivery was correct in accordance with the actual order. Any deviations between expected and actual received goods are noted and reported into the data system. Once the inspection is concluded, material might be, depending on the type of cargo, re-packed on pallets or other carriers, and subsequently transported to outdoor warehouses called external storages hereafter WX1-WX7, except for bulk material and customer ordered items which are moved directly to specific operations or to indoor warehouses called internal storages hereafter (WY8 and WY9), as well as to the storage facilities surrounding AL2 (WZ10).

From the external storage areas, material is moved inside the plant to different internal operations. Most part of the material is sent to manufacturing operations taking place within the company’s plant - panel production (3), cutting and refinement of aluminium profiles (4), fans production (6) and framework production (7). From these manufacturing areas, the material is delivered directly to the storage facilities within AL2 (WZ10), or to a work in process zone, identified by area 5. Components are then picked from WZ10 and used by assemblers at the line (8) during the assembly process. Electronic devices coming from area 9a and 9b are also installed on the unit. Once the semi-finished module is completed, it is moved to area 11, where electronics and cooling devices (if installed) of the units are tested. Finally, the finished module is transported to area 12 for the packaging process, before leaving the plant.
Figure 17: Material flowchart at IV Produkt (Dagberg, Thorén, Tozzi & Velichkov, 2013)
4.3 The order to delivery process from material supply functions to the Assembly line 2

The collection of data regarding the order to delivery process from material supply functions to Assembly line 2 (denominated S-Line 3140/ Flexomix, hereafter called AL2) was conducted considering specific modules/units which are the most frequently produced within the studied assembly line. By focusing on these standard modules and units, it will be possible to obtain analytical results which could be further on generalized and extended to the other assembly lines.

A stratification of production data gathered for the full year of 2012, visualized in Figure 18, shows the number of fan modules assembled on the studied assembly line per unit group. The stratification entitles that the module EXA-300 (the number indicates the size of the module), EXA-190 and EXA-150 are the top three most frequently produced unit families. The logic behind the stratification should help the reader or the user to clearly see which module or unit that have the highest attendance in a descending manner, and by the fact also indicates which unit group the empirical study should be focused on. The idea is that by following one or several top families should give a high and evident hit rate in terms of activities and material movements as the more a module is produced the more repetitive activities and material movements are activated, and by the fact indicating key areas of focus for the empirical study.

Figure 18: All the different modules produced on the AL2 (Dagberg, Thorén, Tozzi & Velichkov, 2013)

EXA-units produced on the AL2 consists mainly of four modules. Two of the modules are designed as fan modules and the other two as filter modules, and are combined in pair of one filter and one fan engineered as an inhale function into the unit, while the other working as an
exhaust air flow out from the unit. An example of an “150 unit” is shown in Figure 19. The fan modules are marked with FA and filters modules with FI.

**Figure 19:** Picture of 150 unit (Dagberg, Thorén, Tozzi & Velichkov, 2013)

In order to get knowledge about the components forming this type of finished modules, two assembly orders (*Code Assembly orders: 723 –335–2 and 7323 -920-4-1*) defining the different material needed to the production of the considered modules were followed. In this way, it was possible to break down the modules into their different components with the aim to empirically identify the flow of each single element and the operations taking place within the plant. Items forming the units involved in the studied order to delivery process are listed in Table 4.

<table>
<thead>
<tr>
<th>Code Component</th>
<th>Name components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>600001-B157</td>
<td>Lucksats EMM-600-40-00</td>
<td>Panel</td>
</tr>
<tr>
<td>600005-B072</td>
<td>Lucksats EMM-600-40-00</td>
<td>Panel</td>
</tr>
<tr>
<td>600001-B015</td>
<td>Lucksats EMM-600-40-00</td>
<td>Panel (support for door)</td>
</tr>
<tr>
<td>600002-B030</td>
<td>Lucksats EMM-600-40-00</td>
<td>Panel (door)</td>
</tr>
<tr>
<td>700043-0003</td>
<td>ANSLUTNINGSPLÅT KOMPLETT 600-WG</td>
<td>Panel (anslutningsplåten)</td>
</tr>
<tr>
<td>70258-1005</td>
<td>KJS-1000-0500-4 KANALSPJÄLL</td>
<td>Air damper</td>
</tr>
<tr>
<td>700054-0009</td>
<td>PGU-RAM 1600*800</td>
<td>Aluminium Framework</td>
</tr>
<tr>
<td>MIE-FD-600-40-E3-063</td>
<td>Fan</td>
<td>Fan</td>
</tr>
<tr>
<td>700048-0150SF</td>
<td>FILTERMONTAGE KOMPLETT S-150 SF</td>
<td>Filtermontage</td>
</tr>
<tr>
<td>13412-0009</td>
<td>KNUT AL H2 RÖDLACKERAD</td>
<td>Corner connection device</td>
</tr>
<tr>
<td>19300-0001</td>
<td>Inspection window</td>
<td>Inspection window</td>
</tr>
<tr>
<td>400006-0015</td>
<td>PROFIL AL TYP H L=1140</td>
<td>Aluminium profile</td>
</tr>
<tr>
<td>400006-0014</td>
<td>PROFIL AL TYP H L=1005</td>
<td>Aluminium profile</td>
</tr>
<tr>
<td>400006-0025</td>
<td>PROFIL AL TYP H L=2070</td>
<td>Aluminium profile</td>
</tr>
<tr>
<td>47033-2098</td>
<td>GLIDSKENA AL UNDRE L=2098</td>
<td>Aluminium profile</td>
</tr>
<tr>
<td>12351-1002</td>
<td>Lamp</td>
<td>Lamp</td>
</tr>
<tr>
<td>12222-1004</td>
<td>Electronic device for lamp</td>
<td>Electronic device for lamp</td>
</tr>
<tr>
<td>/ Wood Pallet</td>
<td></td>
<td>Wood pallet</td>
</tr>
<tr>
<td>47042-1035</td>
<td>PROFIL AL TYP F L=1035 FRASN/BORRN</td>
<td>Aluminium profile</td>
</tr>
</tbody>
</table>

*Table 5: Components involved in the studied order to delivery process* (Dagberg, Thorén, Tozzi & Velichkov, 2013)
The order to delivery process from the material supply functions to the AL2 was observed considering three different material flows:

- Flow A, from WX area (external storages) to WY (internal storage) and WZ (storage facilities within AL2);
- Flow B, from WY (internal storage) to WZ (storage facilities within AL2);
- Flow C, from WZ (storage facilities within AL2 area) to the AL2 (assembly table).

The material flow was delineated by following forklift drivers/pickers and operators at Assembly line 2 in every movements needed to supply or collect the items listed in the assembly order from the different storages surrounding the studied area. During the entire process of supplying and assembling, a specific number of movements were identified for each single flow.

For each movement, the following data were collected: code and description of the component, quantity picked, transportation mode, starting and ending points of operator’s movement, time spent and distance covered. Data gathered from each flow are summarized in Table 5, 6 and 7.

In addition, movements were drawn on the plant map, resulting in two spaghetti diagrams shown in Figure 20 (flow A and B) and Figure 21 (flow C), which will be used to visualize the current state of the material flow within the studied area, and further on in the analysis with the target to propose suggestions on how to improve the studied order to delivery process.

### 4.3.1 Flow A

The flow described in this paragraph is explaining the material movement and supply of components from external storage areas to internal storage areas.

<table>
<thead>
<tr>
<th>Spaghetti line</th>
<th>Code Component(s)</th>
<th>Description</th>
<th>Quantity (units)</th>
<th>Trans. Mode</th>
<th>From</th>
<th>To</th>
<th>Time (sec.)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>780843-0000</td>
<td>Connection panel (fan)</td>
<td>1 pallet</td>
<td>Forklift</td>
<td>WX3</td>
<td>WZ10C4</td>
<td>123</td>
<td>200</td>
</tr>
<tr>
<td>A2</td>
<td>13412-0009</td>
<td>Corner connection device</td>
<td>1 pallet</td>
<td>Forklift</td>
<td>WX3</td>
<td>WZ10C1</td>
<td>116</td>
<td>190</td>
</tr>
<tr>
<td>A3</td>
<td>700048-0150SF</td>
<td>Filtermontage</td>
<td>1 pallet</td>
<td>Forklift</td>
<td>WX3</td>
<td>WZ10C5</td>
<td>135</td>
<td>417</td>
</tr>
<tr>
<td>A4</td>
<td>70228-1005</td>
<td>Air damper</td>
<td>1 pallet</td>
<td>Forklift</td>
<td>WX3</td>
<td>WZ10C6</td>
<td>114</td>
<td>210</td>
</tr>
<tr>
<td>A5</td>
<td>/</td>
<td>Wood pallet</td>
<td>10</td>
<td>Forklift</td>
<td>WX1</td>
<td>WZ10E</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>598</td>
</tr>
</tbody>
</table>

**Table 6:** Table of measurement, Flow A (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Description of the flow

Spaghetti line A1 (from WX3 to WZ10C4), A2 (from WX3 to WZ10C1), A3 (from WX3 to WZ10C5) and A4 (from WX3 to WZ10C6)

Connection panel (fan), corner connection device, filtermontage and air damper are transported directly from WX3 to WZ10C4, WZ10C1, WZ10C5 and WZ10C6 by pickers with the use a forklift, in separate runs. The storage level at those positions are manually controlled (no quantity marks, signals, signs are used) by the picker which triggers the employee to replenish the storage.

Spaghetti line A5 (from WX1 to WZ10E)

Wood pallets are stored in area WX1. From this warehouse, pallets are transported by pickers to area WZ10E with the use of a forklift. The storage level at WZ10E is manually controlled (no quantity marks, signals, signs are used) by the picker which triggers the employee to replenish the storage.

4.3.2 Flow B

The flow described in this paragraph is explaining the material movement and supply of components from internal storage areas to the storage facility within the area surrounding the Assembly line 2.

<table>
<thead>
<tr>
<th>Spaghetti line</th>
<th>Code Component(s)</th>
<th>Description</th>
<th>Quantity (units)</th>
<th>Trans. Mode</th>
<th>From</th>
<th>To</th>
<th>Time (sec.)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>BM Bulk material</td>
<td>*</td>
<td>Walk</td>
<td>WY9</td>
<td>WZ10G</td>
<td>28</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>600001-B157</td>
<td>Panel</td>
<td>1</td>
<td>Forklift</td>
<td>5</td>
<td>WZ10B</td>
<td>156</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td>600005-B072</td>
<td>Panel (support for door)</td>
<td>1</td>
<td>Walk</td>
<td>7</td>
<td>WZ10A</td>
<td>113</td>
<td>146</td>
</tr>
<tr>
<td>B3</td>
<td>700054-0009</td>
<td>Aluminium Framework</td>
<td>**</td>
<td>Walk</td>
<td>WY9</td>
<td>WZ10C1</td>
<td>34</td>
<td>42</td>
</tr>
<tr>
<td>B4</td>
<td>19300-0001</td>
<td>Inspection window</td>
<td>*</td>
<td>Forklift</td>
<td>6</td>
<td>WZ10E</td>
<td>95</td>
<td>126</td>
</tr>
<tr>
<td>B5</td>
<td>MIE-FD-600-40-E3-063</td>
<td>Fan</td>
<td>1</td>
<td>Forklift</td>
<td>9b</td>
<td>WZ10D6</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>B6</td>
<td>400006-0015</td>
<td>Aluminium profile</td>
<td>**</td>
<td>Walk</td>
<td>4</td>
<td>WZ10D1</td>
<td>96</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>400006-014</td>
<td>Aluminium profile</td>
<td></td>
<td></td>
<td></td>
<td>WZ10D2</td>
<td>98</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>400006-025</td>
<td>Aluminium profile</td>
<td></td>
<td></td>
<td></td>
<td>WZ10D3</td>
<td>101</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>47033-2098</td>
<td>Aluminium profile</td>
<td></td>
<td></td>
<td></td>
<td>WZ10D4</td>
<td>103</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>47042-1035</td>
<td>Aluminium profile</td>
<td></td>
<td></td>
<td></td>
<td>WZ10D5</td>
<td>106</td>
<td>86</td>
</tr>
<tr>
<td>B7</td>
<td>12251-1002</td>
<td>Lamp</td>
<td>**</td>
<td>Forklift</td>
<td>9b</td>
<td>WZ10D6</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>12222-1004</td>
<td>Electronic device for lamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Varying according to operators
** Depending on customer demand

Table 7: Table of measurement, Flow B (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Description of the flow

- Spaghetti line B1 (from WY9 to WZ10G)

  Bulk material (e.g. screws, adhesive tapes, glues, handles etc.) and different equipment (e.g. drills, screwdrivers, pliers etc.) needed to assemble the final module are located in a storing area behind the assembly table, denominated as WZ10G (figures on the left).

  Material is procured from the internal storing area WY9 (figures on the right). The replenishment is every Friday, and needed material is refilled to a level upon the operators’ own decision.

- Spaghetti line B2 (from area 5 to WZ10B)

  Panels produced in area 3 are grouped in kit (following the assembly order) and placed on trolleys, which are moved to area 5 (WIP). The trigger for the movement is based on a card signal. When all panels needed for the assembly order are grouped on the trolley, a week number is written on the order sheet with either a green, blue or orange pen visualizing which line and week the wagon is aimed for. When the order sheet is physically put on the trolley, including given information above, gives the signal for movement to area 5. Trolleys are transported from area 5 with a forklift directly to area WZ10B, close to the Assembly line 2, prior the actual assembly of the order. No signals or codes are used to trigger the movement. The forklift driver keeps track on number of waiting trolleys in area 5 versus the production tempo/demand on the assembly line. When the number of trolleys in WZ10B is nearly empty, trigger the replenishment of new panels. Normally the drivers gather 2 trolleys per time.
**Spaghetti line B3 (from area 7 to WZ10A)**

Aluminum frameworks are produced in area 7. They are transported from this zone with a wagon by the producer directly to area WZ10A. The personnel working in the area visually control the actual material level in WZ10A and by that generates the trigger for production and replenishment of new frames. No signals or stock levels are used to highlight the need of replenishment.

**Spaghetti line B4 (from WY9 to WZ10C1)**

Inspection windows are moved by forklift drivers from the internal storing WY9 to area WZ10C1, upon their own decision or by request from operators. When the pallet is nearly empty activates a stock refill equal to a full pallet.

**Spaghetti line B5 (from area 6 to WZ10F)**

Fans are produced in the area 6 and then delivered to zone WZ10F by the forklift drivers. The production and delivery is done in accordance with the assembly order and prior the actual assembly (normally a few days in advance).
✓ **Spaghetti line B6 (from area 4 to WZ10D1, WZ10D2, WZ10D3, WZ10D4, WZ10D5)**

Aluminum profiles are stored in area WX7 and then moved via forklift to area 4, where profiles are cut and refined in different sizes, i.e. different typologies. The same producer transports the profiles from area 4 to WZ10D1, WZ10D2, WZ10D3, WZ10D4 and WZ10D5, via the use of a carriage. The supply of profiles and the control of stock levels in each storage is executed by the producer 6-10 times per day following a specific route. Master planners are also sending demand card highlighting type and quantity of specific profiles needed in the assembly lines. The information is mirroring the actual production demand without considering actual stock levels. The producer evaluates the information given on the card and decides whether to produce or not based on his own knowledge of actual stock levels for highlighted items.

✓ **Spaghetti line B7 (from area 9b to WZ10D6)**

Lamp and electronic devices coming from area 9a are assembled in area 9b and transported by the forklift drivers to area WZ10D6 in accordance with the production frequency on the assembly lines. When the pallet in WZ10D6 is nearly empty, a new pallet is assembled and moved to the storage bin. The need of replenishment is controlled by the electronic assembler or upon request from the assembly line. No signals or stock levels are used to support the decision when to reorder material.
Figure 20: Spaghetti diagram, Flow A and B (Dagberg, Thorén, Tozzi & Velichkov, 2013)
4.3.3 Flow C

The flow described in this paragraph is explaining the material movement from storage facilities within the Assembly line 2 area to the assembly table.

Table 8: Table of measurements, Flow C (Dagberg, Thorén, Tozzi & Velichkov, 2013)

- **Description of the flow**

  - **Spaghetti line C1 (from WZ10B to assembly table)**

    The assembler walks from the assembly table toward area WZ10B to pick the panels forming the module within the air handling unit. Panels are grouped in a kit, positioned on a trolley in order to facilitate the transportation to the assembly table.

  - **Spaghetti line C2 (from WZ10C4 to assembly table)**

    A further panel - connection panel (fan) - is picked from area WZ10C4. Such panel is installed inside the module in order to separate the unit in two air pressure chambers and to support the fan.
✓ Spaghetti line C3 (from WZ10A to assembly table)

Aluminum frameworks needed within the module are picked in area WZ10A.

✓ Spaghetti line C4 (from WZ10F to assembly table)

While the operator is assembling the “skeleton” of the air handling unit, a forklift driver transports the fan from the production (area 6) to the assembly line, in WZ10F. The fan will be further on moved from the floor to the assembly table via the use of a semi-automatic overhead crane.

✓ Spaghetti line C5 (from WZ10C5 to assembly table)

After the installation of the fan, the assembler moves to area WZ10C5 to pick the filtermontage, which will be further on assembled into the unit.

✓ Spaghetti line C6 (from WZ10C1 to assembly table)

The assembler walks from the assembly table to area WZ10C1 to pick corner connection devices, which will be used further on to link the aluminium profiles forming the “skeleton” of the module.
✓ Spaghetti line C7 (from WZ10C3 to assembly table)

The module that will be assembled has a door on one side, needed to let the user of the unit repair the internal devices in case of an eventual damage or dysfunctions. Once the panel is moved from the trolley to the assembly table, handles is installed on it. Panel with the assembled handles is transported by the assembler to area WZ10C3 to drill the hole necessary to assemble the inspection window.

✓ Spaghetti line C8 (from WZ10C1 to assembly table)

Once the panel including handles is brought back to the assembly table, the assembler comes back to area WZ10C1 to pick the inspection window to be installed in the panel. The window is already prepared in a kit, containing screws and a robber tightening.

✓ Spaghetti line C9 (from WZ10D1 to assembly table), C10 (from WZ10D2 and WZ10D3 to assembly table) and C11 (from WZ10D4 to assembly table)

The required typologies of aluminum profiles are picked up from areas WZ10D1, WZ10D2, WZ10D3 and WZ10D4. This storage zone is composed by separated racks with several levels of shelves. The assembler does not walk around the assembly area, i.e. by following walking path to reach the required shelves, but on the contrary he crosses in between to racks in order to shorten the walking distance. Four typologies of aluminum profiles are picked and two of those are collected together in the same picking loop.

✓ Spaghetti line C12 (from WZ10D6 to assembly table)

The assembler walks to area WZ10D6, which is located farthest away from the assembly table. The lamp is picked together with an electronic connection device.
✓ *Spaghetti line C13 (from WZ10E to assembly table)*

To be able to transport the module after the finished assembly process, a wood pallet is needed to be positioned on the assembly table as a first action before the assembler continues the process. From this step, the module is assembled upon the pallet. The pallet is picked by the assembler from area WZ10E.

✓ *Spaghetti line C14 (from WZ10D5 to assembly table)*

A side of the module consists of two panels: one is the door (panel with assembled handles, including the inspection window – see spaghetti line C7) and the other is aiming to cover the remaining space between the door and the outer corner. The final aluminum profile needed to support the panel itself is picked by the assembler from storage WZ10D5.

The pictures below illustrate different phases of the assembly process. The different components are progressively combined together over the course of 3.5 hours on a single assembly table. The first figures on the left gives an idea about the available space needed by assemblers to move among different zones and pick material within and around the studied assembly area.

During the process described in Flow C, bulk material and different equipment needed to assembly components are taken by operators on WZ10G, i.e. small storage areas (illustrated by picture on the left) placed behind the assembly table.
Figure 21: Spaghetti diagram, Flow C (Dagberg, Thorén, Tozzi & Velichkov, 2013)
4.4 Picking frequency of components involved in the order to delivery process

The assembly line is using several types of components in order to build the final air handling unit. This has naturally an impact on the handling of the material in terms of picking or supplying frequency, which also can be titled replenishment runs. Data over all components used by the assembly line during the assembly process were taken from IFS system subtracted into a spreadsheet working as a database for the empirical study. Production data consisted of article number of each component, material description and total number of units consumed during 2012 assembly process per each component (Table 8). Further on, the table also highlights the number of replenishment runs per component conducted by forklift drivers/pickers or cutting personnel as well as assemblers picking frequency of the component during the assembly process.

<table>
<thead>
<tr>
<th>Number</th>
<th>Article number</th>
<th>Description</th>
<th>Nr. of units consumed (2012)</th>
<th>Forklift/Cutting/ Picking</th>
<th>Assemblers picking fq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>144</td>
<td>400006-0127</td>
<td>PROFILE AL TYP H Lw=630</td>
<td>120</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>145</td>
<td>400006-0133</td>
<td>PROFILE AL TYP H Lw=1355</td>
<td>16</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>146</td>
<td>700012-0034</td>
<td>LUCKSATS EMM-150-25</td>
<td>253</td>
<td>127</td>
<td>253</td>
</tr>
<tr>
<td>147</td>
<td>700012-0072</td>
<td>LUCKSATS EPA-150</td>
<td>72</td>
<td>36</td>
<td>72</td>
</tr>
<tr>
<td>148</td>
<td>700043-0003</td>
<td>ANSLUTNINGSPÅLT KOMPLETT 600-WG</td>
<td>293</td>
<td>30</td>
<td>293</td>
</tr>
<tr>
<td>150</td>
<td>MIE-FD-600-40-E3-083</td>
<td>Fan</td>
<td>293</td>
<td>293</td>
<td>293</td>
</tr>
<tr>
<td>152</td>
<td>12351-1001</td>
<td>Lamp</td>
<td>1551</td>
<td>16</td>
<td>1551</td>
</tr>
<tr>
<td>153</td>
<td>12222-1204</td>
<td>Electronic device for lamp</td>
<td>1551</td>
<td>16</td>
<td>1551</td>
</tr>
<tr>
<td>154</td>
<td>700012-0127</td>
<td>Lucksats EMM-600-40-00</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>155</td>
<td>MIE-FD/EFA-150</td>
<td>flakt</td>
<td>325</td>
<td>325</td>
<td>325</td>
</tr>
</tbody>
</table>

Table 9: Database regarding components used by the assembly line
(Dagberg, Thorén, Tozzi & Velichkov, 2013)

The replenishment and picking frequency and how it is calculated must be further explained as it has a vital contribution to the empirical reliability. Considering the replenishment of material from external storages to internal storage areas or storage facilities surrounding the assembly line as well as from internal storages/material supply functions to storage facilities surrounding the assembly line, are mainly conducted via the use of forklifts or wagons moved by feet. The choice of replenishment mode is based on the type of component category in terms of size and weight. All components associated with air dumpers, filter montages and connection panels for fans are moved from supplying functions/storages to storage facilities surrounding the Assembly line 2 with the use of a forklift. Each forklift run for the specific component contains of one pallet equal to 10 units. The assembler is generally picking these components unit by unit in accordance with the assembly order. The aluminium profiles are on the other hand produced and replenished
following a lot size of 50 units and are picked generally 4 at the time by the operator during the assembly of the customer order. The replenishment of aluminium profiles is carried out via the use of wagons moved by the operators working in the aluminium profile department, where profiles are cut and further on supplied to assembly lines. A table of computing keys used to measure replenishment frequency is shown in Table 9.

<table>
<thead>
<tr>
<th>Type of component</th>
<th>Number of units per replenishment run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air dumper</td>
<td>10</td>
</tr>
<tr>
<td>Aluminum framework</td>
<td>10</td>
</tr>
<tr>
<td>Connection panel (Fan)</td>
<td>10</td>
</tr>
<tr>
<td>Corner connection device (with rivet nut)</td>
<td>5000</td>
</tr>
<tr>
<td>Corner connection device (Red painted)</td>
<td>2100</td>
</tr>
<tr>
<td>Corner connection device (Plastic)</td>
<td>2100</td>
</tr>
<tr>
<td>Electronic device for lamp</td>
<td>97</td>
</tr>
<tr>
<td>Fan</td>
<td>1</td>
</tr>
<tr>
<td>Filter montage</td>
<td>10</td>
</tr>
<tr>
<td>Inspection window</td>
<td>50</td>
</tr>
<tr>
<td>Lamp</td>
<td>97</td>
</tr>
<tr>
<td>Panel kit</td>
<td>2</td>
</tr>
<tr>
<td>Profile (Aluminum)</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 10: Computing keys used to measure number of replenishment runs

(Dagberg, Thorén, Tozzi & Velichkov, 2013)

As shown in Figure 22, the assembly line is using 169 component types given an individual article number divided into 14 component categories, which are distributed in percentage illustrated in Figure 23. The top three categories are: 1) aluminium profiles consisting of 76 profile types 2) air dumpers consisting of 41 types and 3) filter montage. On the contrary, one sort of lamp is assembled into the unit likewise just one sort of inspection window and so forth. Further on, Figure 24 visualizes the total number of units consumed per component category during the assembly process, highlighting that top three categories are: 1) profile (aluminium) tracking a total consumption of 158150 units, followed by 2) corner connection device (with rivet nut) 114324 units consumed and 3) corner connection device (red painted) 36716 units consumed, which are distributed in percentage illustrated in Figure 25.
Figure 22: Total number of component types within each component category (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Figure 23: Total number of units consumed per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Figure 24: Total number of units consumed per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Figure 25: Distribution of the consumption (%) (Dagberg, Thorén, Tozzi, Velichkov, 2013)
4.5 Operators’ opinions about the daily work
Two different surveys were conducted, one for the operators at AL2, and the other for the teams in charge of supplying the studied assembly line.

➢ Questionnaire 1 – Operators assembling the module at AL2
The first survey was answered by seven respondents working as assemblers/operators on Assembly line 2. All of them were men. The respondents’ age, number of years working at IV Produkt and number of years in the current position are shown in Table 10.

<table>
<thead>
<tr>
<th>Respondents’ ages</th>
<th>Number of years in the firm</th>
<th>Number of years in the current position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 16-25 years old</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 26-35 years old</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 26-35 years old</td>
<td>2-4 years</td>
<td>2-4 year</td>
</tr>
<tr>
<td>Between 16-25 years old</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 16-25 years old</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 36-45 years old</td>
<td>&gt; 11 years</td>
<td>2-4 year</td>
</tr>
<tr>
<td>Between 16-25 years old</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
</tbody>
</table>

Table 11: Personal information about the respondents (Dagberg, Thorén, Tozzi & Velichkov, 2013)

It was only one of the seven respondents which did not have any experience from another department or areas of responsibility within the firm, and he was one of them who only has worked in IV Produkt less than one year. It was also only one of the assembly workers which was not needed to move to another department or areas outside their regular working place in order to perform his task. The other six, in need to move to other areas, explain that this movement is done by walking or using kick bikes throughout the entire factory, especially to the aluminium panel and fan departments. Those movements are repeated nearly 1-6 times per working shift, resulting in that the employees need to spend between 11 to 60 min to physical move themselves per shift.

The assembly workers could see several areas for improvements regarding the physical work in order to minimize heavy lifting activities by investing in more efficient lifting equipment, for example, by developing lifting loops on bigger batteries could lead to that they do not need to lift them by hand anymore. The physical work create, on the other hand, variation which some of the respondents think is positive with the work today. For instance, one of the respondents appreciates that the firm has invested in adjustable assembly tables which makes it easier to carry out different operations.
All the respondents answered that they are needed to pick items or components outside their working area 1-3 times per shift in order to be able to perform their duties, which approximately take between 1-31 minutes. Where exactly the respondents are needed to walk to pick the material depends on the air handling unit going to be produced, but it is most common that they need to take material from other assembly lines, aluminium profiles department or fan production department. This picking activity is done by walking or using kick bikes, but sometimes they need to contact the forklifts team to pick bigger or heavier articles or components which are placed in external storage areas. The communication with forklift drivers is mostly working well, according to the respondents. Only few operators think that the collection and picking of items is working well today, needed components are relatively close to them and everyone knows where all items are placed, even if they recognize the need for improvements in picking activities. An idea for improvements is to sort all articles in accordance with the specific size of the module or air handling unit, so the material for a specific unit will be placed in the same location. Another suggestion highlighted by respondents is to increase the use of carriages to pick material.

The internal communication between the different departments within the firm has, according to the respondents, some shortcomings which have led to that information is not communicated on time. It happens rather often that some items are not available in the relevant place when they are required, and such issue regards especially fans, batteries and panels, resulting in that operators often try to find them by themselves before calling and asking for help from the forklift drivers, or before to order a new one. Due to this, operators are losing time by searching or waiting for the material. This waiting time varies for the different items, but it can approximately take between 11 minutes up to 2 hours until the needed component is available again. According to the respondents, a common reason why an article is not available on time is connected to the poor delivery accuracy and low level of cooperation between departments and managers. The majority of respondents would like to have the material closer to the Assembly line 2, especially considering special aluminium profiles. They appreciate that the company is supporting them with several pickers, and also value that the firm is working intensively with the development of the material handling. On the other hand, assemblers would like to have an even better communication with forklift drivers and accessibility to resources.

A meeting is held once per week with the aim to highlight the most important facts that have happened during the past weeks within each specific department, but also to information about the present performance, such as account receivable and payable, in order to let the employees
understand the firms’ current and future financial situation. These meetings are particularly appreciated by the respondents. This verbal eye to eye communication is the most common communication method used to spread and share work-related information between employees, and is used by specific foreman/supervisor to provide the employees the knowledge and information when a specific task should be carried out. Sometimes this information is communicated too late to the employees and this makes it difficult for the assemblers to know their specific task for the day. The assemblers get, during this verbal communication, a weekly order list showing the working task he has to fulfil during that week. Even if most of the tasks are carried out according to the lists, there are some other assembly activities which are communicated via a verbal instructions by managers. Respondents do not have any specific routes to follow while picking and preparing the material for the assembly order. In other words, they move within the plant as they prefer, following which is, according to them, the simplest and easiest way to collect material and carry out their tasks.

The respondents feel that the communication is not highly developed within the firm and is needed to be improved. One of them state that all information should be broadcasted as soon as possible to the workers, in order to avoid lacks of information and delays in getting the required data which complicate the daily work. Respondents state that they have generally a good knowledge about the activities performed by employees within the same working area. The knowledge about activities performed by employees outside their area of responsibility is on the other hand low. The same issue appears with the material flow within the firm, which is, in general, not well known and understood. Only workers who have been in the company for long time have a higher knowledge. In order to minimize this knowledge gap, one of the respondents propose to increase the numbers of meetings between operators and managers.
Questionnaire 2 - Operators supplying Assembly line 2

The second survey involved eight men, six of them working as forklift drivers/pickers and two of them employed in the aluminium profile department. The respondents’ age, working area, number of years working at IV Produkt and the number of years in the current position are shown in Table 11.

<table>
<thead>
<tr>
<th>Respondents ages</th>
<th>Working area</th>
<th>Number of years in the firm</th>
<th>Number of years at the current position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 36-45 years old</td>
<td>Forklift driver/picker</td>
<td>2-4 years</td>
<td>2-4 years</td>
</tr>
<tr>
<td>Between 36-45 years old</td>
<td>Forklift driver/picker</td>
<td>2-4 years</td>
<td>2-4 years</td>
</tr>
<tr>
<td>Between 36-45 years old</td>
<td>Alum. profile dep.</td>
<td>2-4 years</td>
<td>2-4 years</td>
</tr>
<tr>
<td>Between 26-35 years old</td>
<td>Alum. profile dep.</td>
<td>0-1 year</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 46-55 years old</td>
<td>Forklift driver/picker</td>
<td>11 years or more</td>
<td>5 years or more</td>
</tr>
<tr>
<td>Between 46-55 years old</td>
<td>Forklift driver/picker</td>
<td>11 years or more</td>
<td>0-1 year</td>
</tr>
<tr>
<td>Between 26-35 years old</td>
<td>Forklift driver/picker</td>
<td>5-10 years</td>
<td>0-1 year</td>
</tr>
<tr>
<td>56 years old or older</td>
<td>Forklift driver/picker</td>
<td>5-10 years</td>
<td>2-4 years</td>
</tr>
</tbody>
</table>

Table 12: Personal information about the respondent (Dagberg, Thorén, Tozzi & Velichkov, 2013)

All respondents have the need to physically move to another department/area to fulfil their tasks, which is to serve the assembly line with material so assemblers do not need to leave their work areas to pick the material. In this way, the respondents need to move around the entire factory. For two of the employees at aluminium profile department, those movements are done by walk, while the other operators are using kick bikes and forklifts, spending between 1-4 hours during a daily work. Regarding the current physical work, the respondents appreciate that they have unrestricted work which allow them to get exercise via physical movements, and that the firm has bright and clean facilities with even temperature and ergonomic working tables. Suggested improvements for the working environment are to make the working place more lighter, for instance by having larger windows or increase the number of them, and by placing plants in the facility. They would also like to see improvements by minimizing the high noise level and heavy lifts which they have today. These improvements could be reached via investing in more smooth lifting equipment. In the recycling handling, it could be better to invest in container which demolish and squeeze the material in order to minimize the space. One other point is to gather
80% of the materials in the department with the aim to reduce the running for the workers on the assembly line, resulting in saving time.

According to all of the respondents the collection and picking of items are well developed, due to a good dialogue with storage clerks who make it possible to easily find the material. Two respondents which work in the aluminium profile department suggest to add more space for different profiles to make it easier to find the specific profile they are looking for and minimize the time to get it out from the warehouse. However, all of them feel that items are not available in the appropriate place when they need them and they assume that it is the result of order delays and short lead times. One of the forklift drivers also explains that sometimes it happens that the team working at assembly line is working too fast, so they are not able to supply material at the same pace. If material is not available when required, forklift drivers react by notify the supervisor in charge for the specific department both via verbal communication or using the information system. By doing so, they can understand when the product will be delivered to the company. One other option is, according to same respondents, to flag the missing item in the IT system, so the procurement office is aware of such lack and can order the article. For instance, it is normal that motors, impellers and batteries are not available when required.

Concerning the material handling, the respondents appreciates that the firm is working a lot with development in this area, and it has created a better structure and order of the material than before, but at the same time they believe that this should even be better organized to be able to optimize the flow. They also would like to see improvements in the labelling of items and in the communication with operators and managers, since the current internal information sharing does not work well. In particular, a lack of communication regarding the need of material is highlighted by the respondents, since it often happens that pickers find out that the assembly line should have the material right away, which means that they get the information too late and cannot satisfied the assemblers. A proposal from one of the forklift drivers is to control material requirements through the IFS data system, for example when an order starts the system would break it down to generate a priority among picking tasks in order to get the material on time. Today the verbal communication (eye to eye or phone) is the most commonly used, but forklifts driver can also gain information via informational boards, while two operators at the aluminium profiles department use intranet. One of the respondents explain that by using a verbal information sharing make it easier to communicate with all workers at the production. A main difference between forklift drivers and other pickers is on how they get information about when a specific task should be carried out. The group of forklift drivers collect information by
themselves when they look at the shelves to see what needed to be replenished, but also via verbal ordering from assemblers. The operators at the aluminium profiles area are instead gaining information by a working list which master planners deliver to them, from which they gain knowledge about the future needs. How the respondents pick the material, i.e. which route should be followed, is not specified. Respondents decide by themselves what is the simplest and easiest path to follow, so that items will be procured on time.

It was just one of the respondents which does not have any work experience from another department within the company. In overall, respondents have a very good understanding regarding the tasks to be carried out within their own responsibility area. On the other hand, a lack of information about activities conducted in the other areas of the firm is highlighted from the surveys. Most of the respondents suggest that this information could be gathered by executing different other tasks, so that they can understand and see how the operations within the firm are structured. Considering the knowledge about the current material flow, employees supplying AL2 feel that they have a good understanding of the present flow, but they are suggesting to have some internal training or courses in logistics, in order to get a wide perspective of the internal order to delivery process.
5. Analysis

This chapter analyses the empirical data in accordance with the theoretical chapter, with the aim to answer presented research questions, as visualized in Figure 26.

The chapter starts with an overall analysis of the entire order to delivery process taking place within IV Produkt. Providing an understanding about how company is working today in the overall process is important to better comprehend the studied area of focus, i.e. the current order to delivery process from supply functions to Assembly line 2. By describing the latter, findings to answer RQ1 are provided.

Through the study of the current flows, several weaknesses of the considered order to delivery process have been identified. That is the reason of introducing a second paragraph, where an ABC classification of the items involved in the considered process is introduced and described as one of the methods suggested with the aim to improve the current material flow. The ABC analysis, combined with Kanban and suggestions for improvement in the current communication and information system, is focusing on minimizing the risk of material shortage and waiting time. By analysing the current flows through the use of the described methods and tools, several findings to answer RQ2 were provided.

Finally, the aim of the third paragraph is to implement the described logic of ABC analysis in order to construct a new layout of the inventory, answering in this way to RQ3. The proposed structure is leading to a new material flow, and consequently to different result in terms of covered distance and time spent during material movements. Providing new ideas in terms of new physical storage will contribute to the improvement of the current order to delivery process, supporting findings presented in RQ2.

Figure 26: Framework of the analysis chapter (Dagberg, Thorén, Tozzi & Velichkov, 2013)
5.1 IV Produkt’s order to delivery process

5.1.1 Overall analysis of the entire order to delivery process

IV Produkt’s entire order to delivery process starts with the identification of the customer needs and ends with the final delivery of the finished products and invoice to the customer. The description of such process is in line with the definition provided by Okongwu et al. (2012). In accordance with the authors’ description, all activities involved within the studied firm are initiated by a customer order which triggers all operations, from material supply functions to the logistics activities needed to make the product ready for the customer in accordance with the agreed delivery time. Lambert and Stock (1993) explain the importance of accuracy in supplying the required quantity and quality of products to meet customer’s requirements. By studying the full order to delivery process within the company it was possible to note that the management put a lot of efforts in guaranteeing such accuracy, by having, already in the start of the process, a high focus on the communication with the customer, with the aim to develop the specific order exactly in line with its needs. According to Okongwu et al. (2012), such approach permits the order to go smoothly through all activities within the process so that goods are delivered as planned. In order to make it possible, it is important that the managers have an understanding on how the different activities are linked to each other, and how they influence one and another’s performance. To gain this knowledge, Jonsson (2008) proposes to map the process, which makes it possible to carry out the different activities in order to define the relationships between the different actions.

Activities taking place in the overall order to delivery process, from the identification of customer demand ending with the final deliver of the order including invoice, are shown in Figure 16.

5.1.2 The order to delivery process, from material supply functions to AL2

As the scope of the thesis is to provide IV Produkt with proposals regarding how the order to delivery process of raw material, from material supply functions (i.e. all supply activities taking place after goods reception and before the final assembly) to the Assembly line 2, can be improved, the remaining part of the analysis will be focusing on the specific area within the company’s order to delivery process, in accordance with Figure 3.

The idea to focus only on a specific part of the overall order to delivery process is supported by Mattson (1999, p.38), who explains the possibility to have an internal perspective of the supply chain within a company in which each actor “can be regarded as customers and suppliers to each other and it is through their combined efforts that the company can produces and delivers products to external customers”. Following this logic, it is possible to focus on a specific part of
the order to delivery process, by seeing the assembly functions, i.e. the Assembly line 2 within IV Produkt, as the customer, and forklifts drivers/pickers and the personnel at manufacturing departments, as suppliers and intermediates.

Analysing the circumscribed order to delivery process taking place between the material supply functions to the Assembly line 2, it will be possible to have a deeper understanding on how material and information flows are constructed today and how they are linked to each other. To be able to identify the different activities within the considered order to delivery process, a process map can be developed, with the aim to get a deeper knowledge regarding both the material and immaterial flows within the company’s plant (Goel, et al., 2005). This tool is also described by Jonsson (2008), which explains that by developing a process map it will be possible to have a higher knowledge about the structure of indicated flows within a company. Figure 27 visualizes the studied order to delivery process.
From a first analysis of the studied process, the material management approach used by the firm can be defined. Following the definitions provided by Jonsson (2008), it is simple to classify the company’s approach as a mix between push and pull material management. In fact, most of the production takes place on customer initiative and that permits to understand that the firm is using a pull approach. As mentioned in their mission, IV Produkt is a company specialized in providing products tailored to meet customer’ needs, so that most of the purchasing, planning,
manufacturing and other types of internal and external activities should be initiated by customer order. This approach permits IV Produkt to benefit by a series of advantages, previously described by Kher et al. (2000). At the same time, part of manufacturing processes and movement of material is triggered by the company’s team of master planners, and this identify the use of a push material management. By keeping such approach, the studied firm is able to shorten lead time and react faster to the customer’s order. On the other hand, a main consequence of adopting this strategy is linked to a high inventory level, resulting in an increased tied up capital, as stated by Lambert & Stock (1993). Such issues characterize the current situation of IV Produkt, due to the fact that often operators tend to order new items from purchasing department when they are not able to find them in the inventory, without considering the consequence of keeping a high stock level.

As described in the theoretical chapter, the studied order to delivery process is not only based on the material flow, since this flow should also be supported by a well implemented information flow in order to guarantee an efficient process (Okongwu, et al., 2012). That means that the information within IV Produkt should be well communicated to all different departments in order to have a well-developed order to delivery process and an efficient material flow. This is also in accordance with Liu & Liu’s (2008) explanation, when stating that both material and information flows should be linked to each other with a customer perspective in focus. The studied order to delivery process is based on four main activities, as described below:

[Activity 1: Identification and planning of requirements]

In the process map, it is possible to note that it is the demand communicated via the customer order which trigger the start of the process, which is in line with Mattsson’s (1999) description. In that sense, it is the information flow which starts the process. In accordance with the same author, this process continues by identifying the need of material, via the use of IFS (the company’s ERP system) or via direct requisitions.

Master planners enter customer orders into the IFS system as a continuous daily work, constructing the customer order book from a data system point of view. Subsequently, activity (1) starts as soon the same planner begins to group and structure the overall requirements for the week which will be further on communicated to the different departments with the aim to deliver the order according to the customer demand. The master planning department makes a general plan over the production, with the help of the data system, which counts down backwards to give the information about when the production of each specific component is needed to start, with the
aim to deliver the order on time. This plan is sent via IFS to the different manufacturing departments, which are panels, fans and assembly lines with exception of the aluminium profiles department, which receives the data via a card system. In the whole order to delivery process, shown by Figure 16, the master planner also sends out information to the purchasing department, in order to communicate the material requirements to be eventually purchased from external suppliers if the material is not in store. The latter activity is not concerned in the present sub-process, as it can be noted in Figure 27, due to the reason that such activities, carried out by internal suppliers, are not considered in the area of focus for the present thesis.

➔ Activity 2: Production planning

The next step in the process map is represented by activity (2), when different departments receive information via the IFS from master planners. Such information concerns how much the different departments are needed to manufacture (quantity) and when production should be finished (date).

It was possible to note via the empirical observation that IV Produkt does not use the IFS system in its full scale to communicate information between employees and departments. The firm prefers to use paperwork and verbal information sharing, and that does not fit with Mattsson’s (1999) description since, according to him, profitable companies should use data system as much as possible to broadcast information on time in order to perform working tasks. The entered information in the system could be seen as a database, which management and specific functions could use to search and extract needed information from. In this way, the data system should be used as a helping tool to communicate information to other members in the different departments (Okongwu, et al., 2012). Moreover, the Activity 2 can be divided into three parts:

- Activity (2a): Production planning conducted by the line manager

As can be seen in Figure 27, during the activity (2a) the manager at Assembly line 2 receive the information about how much the line should produce during the week. The manager at this line extract this information from the IFS system into an excel sheet in order to structure a production plan for the weekly task needed to be carry out by the line, respecting the capacity of working hours and order dates. By doing so, managers produce a working list for the operators within assembly line, with the aim to give the employees an understanding about the operations to be conducted during the week. These lists are delivered to assemblers during the weekly meeting between assemblers, forklift drivers/pickers and managers. This eye to eye communication method is the most common method used in IV Produkt to spread information within the firm.
Meeting are also appreciated by the respondents taking part in this study, according to which this form of information sharing is extremely beneficial for the firm, since it gives the employees a feeling of being involved in company’s activities for the fact that they can value the contribution of their performances. By integrating different categories of workers to make important decisions, they can feel a sense of ownership, and therefore become more willing to improve the process, as explained by Evans & Lindsay (2005) while describing the importance of involving employees in the construction of flowcharts. On the other hand, employees at assembly line believe that such production and information meetings should be organized more frequently.

Chibba & Rundquist (2009) explain that companies are focusing only to have a well-supported information flow for the material handling by using data systems, but most of them are missing the fundamental aspect to educate and introduce the use of such system among employees, resulting in a lack of understanding on how to use it in the daily work. This is partly the case for IV Produkt, due to the fact that the firm has not implemented the data system within all activities taking part in the studied order to delivery process.

- **Activity (2b): Production planning conducted by managers at fan and panel productions**
  
  Activity (2b) starts when managers at the fan and panel productions receive the information about the weekly production requirements via the IFS system. Subsequently, they structure a weekly manufacturing list, detailing the tasks to be carried out by employees. As can be seen in Figure 27, this activity is not included in the considered sub process, since this is an activity outside the studied area of focus. The reason is that the attention is given to the process of supplying the output coming from the production, and not on the internal operation within the manufacturing departments to produce the output. By following Mattsson’s (1999) logic, the fan and panel departments could be seen as suppliers to Assembly line 2, while forklift drivers and pickers are only intermediates.

- **Activity (2c): Production planning conducted by managers at aluminium profile department**

  Activity (2c) takes part in the aluminium profile department, which is distinguished from the other two production departments, since it is following an own set up. Workers in such department receive, from master planners, information about the demand of profiles for the following two/three days. Such information are continuously communicated, more than once per day. Data is printed out by the workers at the aluminium profile department in a “card” format.
The information provided by the cards should be seen as a pure profile demand, not highlighting the difference between the demand and the actual stock level of each specific profile entered in the card. Cards are used by the cutting personnel as an input during the replenishment run to control if the quantity of profiles in the related storage area is matching with the requests, or if additional profiles are needed to be produced. If the quantity is not sufficient, the workers mark it on the card and continue their replenishment run around the assembly area. Workers are also adding information on the card regarding other items which are eventually missing in the storages. When the route is completed, the workers have a new list of information about the needed profiles to be produced. The worker can either use the list to start the production by himself or he can give it to other colleagues in the department who will manufacture the profile and then deliver them to the storage facilities within Assembly line 2. In this way, the list developed by the workers contains the needed information which will trigger the start of the material flow. When the “card” including replenishment runs and production is completed, it is manually handed-in to the master planners who will register the data into the data system.

Spaghetti line B6, showed in Figure 20, illustrates the route involving the movement of aluminium profiles. Replenishment run are conducted between six to ten times during one working shift. During this activity, employees at the aluminium profiles department are assumed to lose time and this could be seen as a waste, according to lean logic explained by Andersson et al. (2006). The purpose with the lean methodology is to identify and eliminate all those activities in supply chain management-related processes which do not add value from the customer’s point of view, allowing the firm not only to be more responsive to the rapid changes of market demand, but also to show a higher customer orientation (Seth & Gupta, 2005). The authors’ statement highlights the need for IV Produkt to develop the information flow to and within the aluminium profile department, in order to decrease the numbers of runs conducted during a working shift, to minimize waste and to gain a well implemented information flow to make material movements more efficient.

⇒ Activity 3: Picking and delivering of items by the forklifts drivers/pickers to storage facilities within Assembly line 2

In activity 3 the physical material handling within the flow is gaining a central role. During this activity the material is moved from external or internal storages to storage facilities within AL2. According to Liu & Liu (2008), both the information and material flows should be well connected with each other in order to gain efficiency in the performance within such activity. Lean and Six Sigma concepts should be kept in mind during this phase of the order to delivery
process, in order to avoid any ineffective performance, for example unnecessary movements of the material between different inventories which do not create any value for customers (Jonsson, 2008). According to Talip et al (2011), a spaghetti diagram could be used, as an important tool to have a more detailed analysis of the actual material movement, due to the fact that it observes the operators’ movement while picking the required items within the inventory. By drawing a spaghetti diagram regarding material flow at IV Produkt, it was possible to see positive aspects of the flow, as well as clear inefficiencies. Observing this diagrams, shown in Figure 20 and 21, it is assumed to be possible to identify waste resulting from an inefficient storage layout and define areas for improvements, to allow a more profitable utilization of the space, as described by Gitlow et al. (1995).

Inefficiencies in the movement of material were well explained by employees within IV Produkt who described how they are working today with the material flow, highlighting different areas which, in their opinion, are needed to be improved. By observing the material flow within IV Produkt (from outside warehouses to the storage facilities within the studied assembly line, passing through internal storages) three different flows were clearly identified (Flow A, B and C). Observing those sub-flows with the help of the spaghetti diagram method, it is possible to note wasteful/redundant trips. In particular, the analysis also highlights that generally there is not a continuous flow of material, often travel distance is long and time consuming and there are many opportunities for product to wait. Moreover, the tracks generated by employees’ movement are confusing and a number of collision points can be identified.

Activity 3 substantially consists on the material supply functions carried out by forklift drivers/pickers to provide the Assembly line 2 with the required material. As shown in Figure 17, articles are picked and collected both from the external and internal storages, and subsequently moved to the assembly area in order to satisfy the internal customer, i.e. assemblers at the assembly line. These performances start when the forklifts drivers/pickers get a weekly list via the IFS system, which is in line with the plan elaborated by the master planner department. The list includes the goods needed to be picked during the week. Picking runs can also be triggered by verbal orders from the assemblers. Forklift drivers and pickers can be seen as a department itself, so the master planners indirectly communicate with them, without the intermediation of a manager. The main issue within this communication set up is that it is only describing to forklift drivers/pickers the list of items needed to be moved during the week, but it is not specifying the picking sequence. This complicates the work for picking operators since, according to empirical data, it seems that they have a lack of information about when the different movements should be
carry out in order to satisfy the worker at the assembly line. They explain that it often happens that pickers find out that the assembly line requires the material right away, which means that they get the information too late and therefore cannot satisfy the assemblers. As a result, it is possible to note that pickers do not have knowledge about the priority with which the activities should be carried out. This is assumed to be linked to the fact that the communication is not highly developed within the company, which creates risks of material shortage and waiting time. As a consequence, the current internal information sharing is not working adequately, as highlighted by the operators participating in the study. According to Lascu (2011) and Jonsson (2008), the lack of information sharing would make the internal and external communication even more complex, leading to the need of a new well-developed communication flow needed to efficiently support the material flow. Moreover, by following Chibba & Rundquis’s (2009) thoughts, the management within IV Produkt has a need to understand how the information system is influenced by the human behaviour and human relations within the company, in order to develop it in a way to cover this lack of information. With the aim to improve the information sharing in activity 3a, a proposal given by forklift drivers was to increase the use of the IFS system to spread critical data all over the company.

In this perspective, a proposal from one of the forklift drivers is to increase the control over material requirements through the use of the data system. For example, when an assembly order is supposed to start, the system should break it down with the aim to generate a priority among picking tasks, so forklift drivers/pickers can collect items in the right sequence, which is in line with Mattson’s (1999) suggestions on the use of data system.

Today forklift drivers also collect information about their task by themselves, controlling the quantity of material in the storage areas around the assembly line, so they can compare the actual stock level with the data provided by the system, as previously explained. This controlling activity can be seen as an extra movement originated by a lack of information regarding their picking tasks. As a result, the pickers are losing time by travelling around the facilities a repetitive numbers of time during a working shift, and this might be seen, according to the lean logic, as a waste, as explained by Andersson et al. (2006). Empirical observations show that assemblers appreciate the work carried out by the forklift drivers/pickers, but they believe that it takes time until the forklift drivers is available for their requests. An assumed improvement in the information flow, in order to minimize the lack of computerized picking assignment, is to decrease unnecessary movements for the forklift drivers, resulting in saved working hours which could be transformed in more available time for the assemblers. This improvement would add
value for the internal customer, as explained by Breyfogle et al. (2001), while describing the logic behind the Six Sigma approach, with the overall aim to increase customer satisfaction.

Another issue which also affect the availability of the forklifts driver is connected with the location of the material within the firm. Empirical data highlights a general dissatisfaction linked to the fact that required material is not placed at a close distance when it is needed. The reason is that the material is widespread all over the factory, which also can be noted by spaghetti diagrams (Figure 20 and 21), as well as by the flowchart showed in Figure 17, following the indications of Gitlow et al. (1995). According the author a layout flowchart should represent the floor plan of a specific area within the company, highlighting the flow of paperwork or goods and the location of equipment, storage areas, file cabinets and etc. The purpose of this flowchart is to identify wastes resulting from an inefficient layout and identify areas for improvement to allow a more profitable utilization of the space (Gitlow, et al., 1995). This wastes can be easily identified since forklift drivers, but also the workers in profiles department, have to move continuously across the plant among different storages and manufacturing departments which are relatively far from each other. By adjusting the layout of the current storage, unnecessary movements of products and materials could be avoided, according to Jonsson (2008).

A further important aspect which is worth to be analysed is that IV Produkt’s managers do not communicate to either forklift drivers/pickers or assemblers which specific route they should follow while picking the necessary material defined in their working list. Instead such operators are required to decide by themselves what is the simplest and easiest path to follow, so that items will be procured on time. In this way the work is not standardized since workers follow their own defined working procedure. However, the firm is assumed to lose knowledge since working procedures are not shared between workers, resulting in a loss of opportunities for improvements and standardization. It can also be assumed that own developed working procedures can have a negative effects on the overall performance within the firm as one area might be “over served”, while another area will not be prioritized, leading to an imbalance in the overall efficiency.

➔ Activity 4: Material movement from the storage facilities within AL2 to the assembly tables

Activity 4 describes how the workers at the Assembly line 2 pick the needed material from storage facilities surrounding the line in order to assembly the requested module. This activity is triggered when the assembler receives the weekly working list during the weekly meeting with the manager of the line. This eye to eye communication is the most common method used to
spread information within and between the departments. The working list is structured in a way that workers get information about all production orders which should be assembled during the current week. This list is mostly followed with a top-down approach. Sometimes the assembler can get verbal information from line manager that some orders needs to be started prior other order in the list, to be able to deliver the requested module to the end customer on time.

Before starting the assembly process, assemblers have to pick and collect the material at the storage facilities within Assembly line 2 and move it physically to the assembly table. How and when the worker should pick the material is decided by themselves, and in that meaning the working procedure is not standardized. The picking runs and walking path are individually decided in accordance on how they build up the unit. Spaghetti lines involved in Flow C, shown in Figure 21, visualizes how the workers at the Assembly line 2 are forced to walk in several runs in order to collect the needed material. The aim of this chart is to provide an overall view of the material flow in the process and show the waste coming from transportation and movements that should be eliminated, driving the company towards a more lean orientation (Talip, et al., 2011).

From the analysis of the empirical data it was possible to note a general dissatisfaction linked to the fact that required material is not located close to the assembly tables. Assemblers are therefore needed to leave their working places to pick the material required to carry out the assembly process. Besides that, the empirical founding highlights a general lack of knowledge regarding the position of the material located in different storages. As in the case of Activity 3, by identifying and minimizing unnecessary movements and lacks in the material flow will generate not only a more efficient flow itself, but it will also facilitate the elimination of not value adding activities, resulting in a higher customer orientation (Seth & Gupta, 2005). In other words, by following the concept of lean and Six Sigma, it will be possible to remove different type of waste within company’s internal environment, through a continuous improvement mentality (Andersson, et al., 2006).

Moreover, a critical problem which is highlighted in empirical chapter is connected with the fact that components are often not available in the relevant place when required. This issue principally involved fans, batteries, profiles and panels. A main reason is, according to respondents, linked to the poor delivery accuracy resulting in order delays and prolonged lead times. The waiting time is also generated by the fact that assemblers are sometimes working with a higher speed than forklift drivers/pickers, who consequently have difficulties to supply materials on time. These aspects on the working process are in contrast with the belief of Kisperska-Moron (1996), according to which delivery reliability is a crucial inventory performance needed to satisfy the
customer requirements. This can also be linked to the lack of communication and information sharing between shop floor managers and forklift drivers/pickers.

- **Bulk Material movement from storage facilities within AL2 to assembly tables**
  From the observation of the empirical data, it was possible to note that bulk materials, such as screws, adhesive tapes, glues and different material and equipment that are picked by assemblers to complete the final module in the Assembly line 2, are positioned in one specific zone (the internal storing area WY9). The necessary material is refilled weekly by assemblers who move to such storage and bring material in a small store behind the assembly table. The quantity picked for replenishment is defined in accordance with the assemblers’ own decision. Therefore it often happens that operators are taking more than the necessary quantity of materials comparing the actual need. By doing so, the inventory level tends to increase. Keeping high amount of materials in stock consumes space and tie up capital (Lambert & Stock, 1993). This replenishment policy is therefore creating waste, which is needed to be eliminated, in accordance with the theoretical concepts of lean and Six Sigma, previously explained by Seth & Gupta (2005), Andersson et al. (2006) and Breyfogle et al. (2001). Also this waste is assumed to be originated by a lack of information, since this excess of material would not be present if available data within the system would be appropriately shared among company’s members (Okongwu, et al., 2012). On the basis of this consideration, the replenishment policy of bulk material can be seen as a further area for improvement.

**5.1.3 Summary of area for improvements**
The weaknesses of the studied order to delivery process, above described, can be summarized in the two following points, corresponding to the main areas for improvement. By defining solutions for both areas, it will be possible to answer respectively RQ1 and RQ2.

- **Lack in the communication and information sharing**
  IV Produkt does not adequately use the IFS system to its fully potential and employees in different levels haven’t got an appropriate training on how to use the system. Moreover, operators complain about the missing of daily information regarding the tasks related to their own responsibility area. As a consequence, information activities are either lacking or conducted with a slow manner. The delay in communicating and sharing information leads to the risk of material shortage and waiting time.
Four key weaknesses can be highlighted as a consequence of the low developed communication and information sharing set-up:

1. **Unnecessary material movement**

   Different unnecessary material movements were identified in the current material flow:

   - Forklifts drivers/pickers move continuously across the plant among different storages and manufacturing departments, since the needed components are spread all over the plant.
   - Operators at aluminium profile department are losing time by travelling around the facilities a repetitive numbers of time during a working shift.
   - Studying the movements done by assemblers, it is possible to note that there is not a continuous flow of material, often travel distance is long and time consuming and there are many opportunities for product to wait.
   - Moreover, managers do not communicate the route which operators should follow while picking the necessary material defined in their working list, which is seen as a loss of opportunities for improvements and standardization.

2. **Lack in time coordination between suppliers of AL2 and assemblers**

   Assemblers are sometimes working with a higher speed than forklift drivers/pickers, who consequently have difficulties to supply materials on time, and this causes order delays and a prolonged lead time.

3. **Inefficient picking activities**

   Assembly operations are negatively affected by the fact that forklift drivers/pickers do not have any knowledge or information about the prioritized sequence regarding how picking activities should be executed.

4. **Incorrect replenishment policies**

   Bulk material is refilled to a level upon the operators’ own decision, therefore it often happens that operators are taking more than the necessary quantity of materials comparing the actual need, leading to an increased inventory level.

- **Storage layout issues**

  Material is widespread all over the factory and it is possible to identify waste resulting from an inefficient storage layout. By adjusting the layout of the current storage, unnecessary movements of products and materials could be avoided.
5.2 Implementation of tools and functions to improve the studied order to delivery process

5.2.1 Improvement of the information flow

As been highlighted, IV Produkt has lack in the current information flow, due to the fact that the communication and information sharing between employees and departments are not well-developed. This can be clearly noted analysing the empirical data, where respondents explain that data regarding the daily working tasks are communicated and received too late, so they are not able to supply the material on time, resulting in material shortage and waiting time for the operators at the Assembly line 2. Consequently, IV Produkt has the need to develop the current information flow with the aim to improve its internal communication system. As Falkheimer & Hei (2007) explain, this system is built on three key fundaments: hierarchical communication, media communication and informal communication. According to the same authors, these three aspects represents the base of the system in order to spread the information through the whole organization. Following the authors’ logic, it is possible to note that those three key factors within IV Produkt are not well-developed today and therefore needed to be improved, since, according to respondents, the firm is lacking in the communication sharing between workers and managers, as well as within the different departments.

Keeping this in mind, it could be assumed that the development of the information system within IV Produkt would result in an optimization of the communication and data sharing through the whole firm, in order to support the material flow, and at same time, creating an effective order to delivery process. This is in line with Okongwu et al.’s (2012) theoretical description. As described earlier, the firm is mostly using verbal communication to share information between employee’s. Chibba & Rundquist (2009) state that this mouth to mouth communication is considered as one of the best method to use, comparing with the use of a data system. This statement could be confirmed for IV Produkt in some areas, especially with regards to the informal communication between workers, but on other hand, other areas within the firm might be assumed to have the need to communicate via the IFS system in order to get information on time. For that reason, the suggested development of the information flow should consider the different communication exigencies characterizing each single department, as also described by Lascu (2011). In this way, by following each single departments and identifying its specific needs, it is assumed that it will be possible to improve the communication system within the studied order to delivery process, in order to minimize the lack in the current information flow.
- The aluminium profile department

Considering the aluminium profile department, workers collect via IFS cards the information about the following two/three days requirement of profiles, which are sent from the master planner department. As early mentioned, those cards do not give enough data to the personnel at the department, in order to perform their working task. Due to this lack in the communication sharing, workers need to collect information by taking a replenishment run around the facilities, with the aim to get the knowledge about which profiles are missing and therefore needed to be replenished. This route is walked many times during one working shift, leading to that the employees spend time in collecting the required information, instead of carrying out their core activity, which is to produce and replenish the needed profiles with a high accuracy. This working structure and information flow is assumed to be inefficient, due to the fact that IV Produkt is missing the interface between the paper system and the database, which is in line with Chibba & Rundquist’s (2009) statement. In accordance with authors’ thought, it could be assumed that by expanding the use of IFS system the master planner would be able to communicate a more detailed data to the workers, leading to a minimization of the number of runs and therefore reducing wasted time at the aluminium profile department. As could be noted in the empirical observation, personnel employed in this department hand in the card to the master planner with information on what the workers have produced and where material is placed in store, which the master planner enter into the IFS system.

By following the proposals from Mattsson (1999) and Liu & Liu (2008), the actual information, which are today already available in the IFS system, could be usefully used by the master planner who could, with the help of this IT system, examine the data to structure a more detailed card, in order to decrease the lack of information which the company has today. This card should therefore be developed to give workers an understanding of which of the aluminium profiles are needed to be produced and how many of these items should be manufactured, based on the correlation of data in the system about quantity in store and the requirement defined in the customer order book (the negative delta between actual stock level and sales forecast or actual customer demand). As a possible result, employees at the department would receive a more detailed card specifying what they exactly need to produce, limiting the need to conduct unnecessary replenishment runs around the facilities at the same frequency as per today. Consequently, in this way, it will be possible for workers at the aluminium profile department to minimize unnecessary work, as well as saving time to collect the needed information.
This data is assumed to be even deeper improved by combining them with the ABC classification mind-set described by Jonsson (2008). By following this logic, it could be possible for the master planner to divide the different aluminium profiles into A, B and C items, and use this knowledge to structure a more developed plan for the production which follows the replenishment frequency. In this way, it is possible to assume that the card received by the worker at the aluminium profiles department, should contain more detailed data about when the different profiles should be produced in the future. For example, the C profiles could be produced only one time during a three weeks period, but with a larger batch size, while the A profiles could instead be kept in more focus and produced more frequently. Consequently, the information could be assumed to be more useful for the workers at the department, since they should just need to collect data via the IFS resulting in a wider knowledge of the future tasks. In fact, the company is assumed to gain a more efficient profile production, decreasing in part the risk of material shortage and waiting time for the operators at the Assembly line 2.

- **Forklift drivers/pickers**

Lack in the information sharing for the forklift drivers/pickers is also originated by the same issues as in the aluminium profile department. As describe before, forklift drivers/pickers receive a weekly working list via the IFS system, shown on a data screen within the forklift. Workers have highlighted a lack of information within this area of focus, complaining that they are missing the prioritized sequence regarding how picking activities should be executed. To be able to collect the needed information, forklift drivers/pickers control the quantity of material in the storage areas around the Assembly line 2, so they can compare the actual stock level with the data received by the system, as previously explained. This implies that pickers are losing time by travelling around, a repetitive number of times during a working shift, in the facilities.

To be able to improve this lack of communication, IV Produkt could be supposed to extend the use of the IFS system, gaining a computerized picking activity trigger i.e. detailing which and when specific components should be picked. For example, as a proposal from operators, when an order starts, the system should break it down to generate a priority among picking tasks in order to pick and supply the material on time, which is in line with Mattson’s (1999) suggestions with the use of data system. In this way an assumption is made that this could improve the forklift drivers/pickers’ knowledge on when they should carry out their specific working tasks. At the same time, by reducing this lack of information, the forklift driver would be able to supply the material to Assembly line 2 with a higher delivery precision, which consequently might be
assumed to minimize the risk of material shortage and waiting times for the operator at the specific line.

However, another issue linked to the priority of working task is connected with the lack in the communication and the information sharing between shop floor managers and the forklift drivers/pickers. This need of improvement is based on the fact that the workers at Assembly line 2 sometimes receive verbal instructions from managers regarding rescheduling of the production sequence, in order to prioritize a specific customer order with the target to deliver the module on time in accordance with customer demands. The same type of information should also be communicated to the forklift drivers/pickers, but this is not the case today, and as a result they are getting the information about their picking tasks too late while the assembly line requires the material right away. In other words, the lack in communication, forklift drivers/pickers and assemblers are working at two different working speeds, resulting in an inefficient flow of the material. As a consequence, assemblers’ needs are not satisfied. Due to that, it could be assumed that when the assemblers receive verbal instructions from the shop floor managers, the information should also be communicated to the forklift drivers/pickers via phone or via a developed function in the IFS system as previously mentioned. Another way to improve this lack of information is still linked to the extending of the use of IT system, as Mattsson (1999) explains. By using the information provided by the IFS system, the forklift drivers/pickers could control the quantity of material in the storage areas around the Assembly line 2 by themselves without physically visit the actual storage position/shelf. In this way, since the system has all the needed information, IFS could, when the required quantity decrease below the defined safety stock, send an order to the forklift drivers/pickers’ computer, so they can replenish the specific item in accordance with a required batch size. In this way, it might be possible to reduce the time spent in collecting the necessary data and, contemporaneously, the forklift drivers/pickers would receive information about the prioritized sequence regarding how picking activities should be executed. As a consequence, it could be assumed that this would lead to a decrease of the risk of material shortage and waiting times for the operator at the studied line.

- Operators at the Assembly line 2
  As described earlier, during a weekly meeting, operators at the Assembly line 2 receive from the line manager a list including information about the orders which should be assembled during the week. This list triggers the assembly process, during which operators need to pick material in the storage facilities within Assembly line 2 and move it physically to the assembly table. How and when the workers should pick the material is decided by themselves, and this is the same for the
picking runs to be followed. In other words, those performances are individually decided in accordance with the assembly sequence.

The main issue that operators have today is linked to the information flow, due to the fact that they are missing knowledge on where the material is placed in the storage. Due to this lack of information, operators are in need to make unnecessary movements, resulting in a waste of time. This is not efficient and does not create any value, in accordance with Seth & Gupta’s (2005) thought. By following Chibba & Rundquist’s (2009) description, improvements can be achieved by increasing the number of meeting between assemblers and line managers, which is also proposed by operators. This suggestion is assumed to increase the information sharing between these two actors and, at the same time, create a high degree of harmony among the workers, which is the key to a real communication, in accordance with Lascu (2011). Following the same author’s statement, by increasing the number of meetings managers would benefit from a higher trust from operators, gaining an improved and efficient communication flow within the department. Another possible proposal is linked to Okongwu et al.’s (2012) statement, according to which, by improving the use of IFS system it could be assumed that the operators should be able to use the data system to search where the required material is stored. By doing so, assemblers would be able to collect the information they are currently missing, and they would not have the need to walk unnecessary rounds. Consequently, it is assumed that this will result in a decrease of the time, which could be more efficiently used to in their assembly tasks, in order to be more customer oriented.

### 5.2.2 ABC Analysis

In accordance with Heizer & Render (2004), products, customers, suppliers or other elements linked to a firm can be categorized into different classes with the purpose to enable a separation and isolate elements that contributes more to the business than others. Applying this classification logic to all components used by the studied assembly line (based on the number of replenishment runs conducted by forklifts, pickers and operators at aluminium profile department), generates a clear picture of which are the components that have the highest frequency regarding replenishment runs, classified as A items, versus components replenished only via a few runs per year, classified as C items (Figure 28). The analysis indicates that 30% of the components used by the assembly line represents 80% of the total number of replenishment runs (classified as A-items), B-items represents 15% of the total number of replenishment runs and finally C-items the remaining 5% of the total number of replenishment runs. The C-items represents, on the other
hand, approximately 52% of the components used by the assembly line which is equal to 88 components. A note can be made that 20% of the components represent approximately 66% of the total number of replenishment runs marked with a ticked line in Figure 28.

**Figure 28:** ABC classification of components based on replenishment runs (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Ng (2007) argues that different classes or groups should be treated differently in a sense that components contributing the most to the business or the area reviewed should get the highest attention. As an example, A components could be physically located closest to the consumer in order to be able to supply those with a short lead time and at the same time minimising non value adding activities in terms of a shorten picking distance. In other words, items that are picked most frequently, i.e. trigger the highest amount of meters walked or travelled, should naturally be located closest to the consumer in order to minimize such distances.

Concentrating the focus firstly on the A items, this class is represented by 51 components (pointed out in the analysis and presented in Table 12) which are picked and used most frequently
by the assembly unit. Those components belong to different component categories, as shown in Figure 29, positioning group profile (aluminium), aluminium framework and connection panel (fan) as the top three replenished categories for A items in terms of number of runs per component type.

<table>
<thead>
<tr>
<th>Description</th>
<th>fLift/Cutting</th>
<th>fLift/Cutting</th>
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<tr>
<td></td>
<td>Nr. of repl. runs</td>
<td>Nr. of repl. runs</td>
</tr>
<tr>
<td>Fan (EFA-150)</td>
<td>325</td>
<td>111</td>
</tr>
<tr>
<td>Fan (FD-800)</td>
<td>293</td>
<td>104</td>
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<td>PROFIL AL TYP H L=990</td>
<td>113</td>
<td>66</td>
</tr>
</tbody>
</table>

| Table 13: Total number of components classified as A items (Dagberg, Thorén, Tozzi & Velichkov, 2013)

![A-Items per component category](image)

**Figure 29**: A-Items per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Using the same approach for the B-items, shown in Figure 30, indicates that 30 components, shown in Table 13, are classified within this group and divided into 11 component categories where profile (aluminium) followed by air dumper and aluminium profile (fan) represent the top three categories (Figure 30).
Table 14: Total number of components classified as B items

(Dagberg, Thorén, Tozzi & Velichkov, 2013)

![B-Items per component category](image)

C-items represents, as already mentioned, 52% of the total number of components used by the assembly line which is equal to 88 physical units, shown in Table 14 and are divided into six different categories (Figure 31). It is clear that profile (aluminium), air dumper and filter montage are representing the top three for the C-item category.
By analysing the data gathered during the spaghetti diagram analysis, it is possible to calculate the total distance covered (in kilometres) and total time spent (in hours) for forklift drivers/picker per component category in order to supply the assembly line. The formula is based on the time and distance required to supply each component in the studied assembly order (as described in paragraph 4.4) multiplied with the total number of runs during 2012 per component type/unit (provided in the database constructed during the empirical study). The result showing...
the total sum of distance covered and total sum of hours spent per component category during 2012, is given in Figure 32 and 33 and relative data for each category in Figure 34 and Figure 35. The information provided, clearly indicates that aluminium profiles (279,1 km), aluminium framework (136,0 km) and air dumpers (100,3 km) represent the top three categories regarding total sum of kilometres covered. The position of top categories was nearly the same regarding the total sum of hours spent during the year except for filter montage positioned as number three in the list. Air dumpers were positioned as number five regarding total time spent.

**Figure 32**: Total distance covered (Km) 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013)

**Figure 33**: Total time spent (h) 2012 (Dagberg, Thoren, Tozzi & Velichkov, 2013)
Figure 34: Percentage distribution of kilometres covered during 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Figure 35: Percentage distribution of total number of hours spent during 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013)
5.2.3 Implementation of Kanban
As previously highlighted, bulk material is refilled to a level upon the assemblers’ own decision, therefore it often happens that operators are taking more than the necessary quantity of material comparing the actual need, leading to an increased inventory level. This is not convenient for the studied company, since keeping high amount of material in stock consumes space and tie up capital (Lambert & Stock, 1993). This replenishment policy generates waste, which is needed to be eliminated, in accordance with the theoretical concepts of lean and Six Sigma, previously explained by Seth & Gupta (2005), Andersson et al. (2006) and Breyfogle et al. (2001). One of the main methods used by companies aiming to implement lean and Six Sigma principles is Kanban, as explained by Dahlgaard & Dahlgaard-Park (2006). Such system will be therefore considered as a proposal to improve the ineffective replenishment policy of the current bulk material, but also for other specific components, such as lamp, electronic device, inspection windows and corner connection device as they can be seen as stock keeping units produced or supplied in large batch sizes.

In order to apply the mentioned method, bulk material in IV Produkt should be kept in standard boxes, each one containing the same amount of articles. A Kanban card should be attached on each box specifying the quantity of items needed to be placed inside the box itself. Boxes are placed behind each assembly table. When box nr 1 is empty, he continues to consume box nr 2. At the same time, assembler places the Kanban card of box nr 1 in a holding case and forward the empty box to the internal storing area, where bulk material is stored. The Kanban card belonging to the empty box will trigger the refill of a quantity of material equal to the amount defined on it. The moved Kanban card is then re-attached on the box, which is moved to the outbound area of the storage. This gives the permission to assemblers to pick the full box on which the card is placed and bring it to the assembly table. This loop is supposed to be repeated time after time every week. The described procedure is in line with the explanation of the Kanban method provided by Slack et al. (2004).

By using the Kanban approach, employees and managers would gain exact information about the stock level of the different items located in internal storing area. Thus, the firm will be able to reduce unnecessary movement of material by decreasing the re-ordering frequency of bulk items or other specific components mentioned before. Moreover, IV Produkt would have a more efficient control over the quantity of bulk material consumed by AL2, by minimizing the “squirrel” mentality which characterize the daily work, since, via the use of such system,
assemblers should not be able to take more material than the amount defined in the card. As a result, this system will allow a reduction of the inventory level and consequently of the different costs linked to keeping a high stock level, while still satisfying the demand from customer, i.e. the assemblers. By keeping a low inventory level and increasing the control on picking activities related to bulk material, will reduce material shortages, as described by Jonsson (2008) and Kumar & Panneerselvam (2007). Further on, following the indications given by Andersson et al. (2006), it could be assumed that with the implementation of this lean tool, the firm will considerably reduce the handling time connected with the refilling of the boxes used during the assembly process as per today.

5.2.4 Summary of functions and tools to improve the studied process

Figure 36 illustrates a summary of findings highlighted in paragraph 5.2.

**Figure 36:** Summarized scheme of paragraph 5.2 (Dagberg, Thoren, Tozzi & Velichkov, 2013)
5.3 New proposed storage layout

5.3.1 Implementation of ABC logic in the storage layout
As stated by Jonsson (2008), unnecessary movements of material can be avoided by adjusting the layout of the store to the processes carried out within, in a way to minimize the physical distance between material, resulting in decreased time and cost of material transportation and handling and higher efficiency in material flow. Unnecessary movements represent a form of waste, which is supposed to be eliminated, in order to implement the principle of lean and Six Sigma concepts described by Seth & Gupta (2005).

Considering the material flow within the plant of IV Produkt, several unnecessary movements were highlighted by describing the current flow through spaghetti diagrams, but also via the analysis of the current studied order to delivery process in the previous paragraph. According to Jonsson (2008), the purpose while designing the layout of a store, is to generate a rational distribution of items, in accordance with their rate of utilization. As a consequence, the reconstruction of the storage layout should be carried out by localizing and distinguishing high-frequency from low-frequency items, with the aim to eliminate different kinds of waste in the transportation of goods (Jonsson, 2008). In other words, the idea is to implement an ABC analysis to improve the throughput of inventory operations, by positioning material within the store in accordance with the demand frequency (Chen, et al., 2010; de Koster, et al., 2007; Caron, et al., 2000). On the basis of these considerations, in paragraph 5.2.2 the studied components were divided into three different classes (A, B and C), following the indications provided by Heizer & Render (2004) and the calculation model explained by Scholz-Reiter et al. (2012). The calculated classification is now supposed to be used to locate components in a new structure of the storage, in accordance with the class they belong to. Analysing in depth the current material flow and its weaknesses, a new layout is constructed and visualized in Figure 37.
Figure 37: The new suggested layout construction (Dagberg, Thoren, Tozzi & Velichkov, 2013)
As it is possible to note, a first action is to create a new storing area where items characterized by the higher picking frequency are located. The new identified storage, titled “NEW12”, will be located in the previous WIP (area 5 in the map) location. The latter is instead moved to the storage facility area surrounding the Assembly line 2. Via this change, items previously located in WIP (panel kits) will be delivered in one single run from supplier (in this case, panel production) to customer (assembly line). The new storing area, as well as the indicated modifications are visualized in Figure 37.

Items with highest frequency, i.e. components belonging to classes A and B, will be stored in NEW12, while C-class items will be stored in other locations, which will be further on explained. An exception among A- and B- class items is represented by two special component categories: fans and panels. The exception for the panel is already explained, while the fans will be kept in the same locations and replenishment run, as in the previous material flowchart.

A- and B-class items will be placed within the new inventory, following the U-shaped format, gaining the benefits linked to this layout described by Jonsson (2008). The Figure 38 visualizes a replenishment tour conducted by forklift drivers/pickers, as well as the picking loop carried out by the assemblers. As it is possible to note, such format of the storage reflects the “milk” logic within a supermarket, where forklift drivers/pickers are refilling components from the storage area on the opposite site of the shelves where assemblers pick the needed material.

Figure 38: Layout of the new to storage (Dagberg, Thorén, Tozzi & Velichkov, 2013)
The reason of introducing this new inventory area is connected to the purpose of reducing the distance of material transportation covered by operators during their daily work. Several advantages linked to this decision can be highlighted.

In the new proposed model of store, forklift drivers/pickers will not have to move A and B items to several different storages spread out in different areas within the plant, as in the previous case, but just to a single inventory zone, saving an assumed considerable amount of time.

Time and travelled distance are assumed to be reduced as a result due to the fact that this new storage area will be located closer to the main material supply functions in terms of aluminium profile production, the inbound gate from external warehouses and partly closer to the production of aluminium frameworks.

As highlighted in Figure 39, A items will be located on shelves and storage bins upfront the inbound gate and the other supply functions, while B items will be stored further back. The motivation of this choice is that A items, having a higher replenishment frequency, should be located close to the supply units, minimizing travelling distances. B components will be still located close to supply functions, but further back respecting the lower replenishment frequency.

Not only forklift drivers/pickers are assumed to gain a benefit from the use of the new storing area, but assemblers are also in their daily picking activities assumed to be positively affected. Firstly, a small negative remark has to be done. As the location of A and B items is moved further away from the previous storage area surrounding Assembly line 2, the assemblers are forced to walk a longer distance to reach the main destination. On the other hand, the transportation movements done by assemblers to pick the required material could be done via a single tour, using a wagon (the same type used by dedicated pickers belonging to the other two assembly lines). In this way, assemblers leave AL2 with the specified wagon, walk in the direction of NEW12 and carry out the picking procedure in accordance with the assembly order picking list. As it is possible to note by the loop visualized in Figure 38, assemblers will pick material via a movement which follow the U-shaped format of the storage layout, as theoretically presented by Jonsson (2008).
Considering the handling of C-class items, Figure 39 shows the new layout for the storage surrounding Assembly line 2. All C items are regrouped and located, in comparison to the previous layout, in the storage below the assembly line.

Figure 39: New layout for the storage surrounding Assembly line 2
(Dagberg, Thorén, Tozzi & Velichkov, 2013)

As C items have a low replenishment frequency, they should, with the assumption based on the logic given by Ng (2007), van Kampen, et al. (2012) and Jonsson (2008), be located farther away from the supply units, as by nature they are not replenished so often, in comparison to A items.
5.3.2 New material flowchart
On the basis of the new storage layout shown in Figure 37, the new material flow taking place within IV Produkt’s plant is visualized below in Figure 40.
From a first analysis of the material flow within the new proposed storage layout, it is possible to note that several material movement paths were streamlined or eliminated, as a result of the introduction of the new storage area NEW12. Replenishment runs taking place from external warehouses to internal storage or storages facilities within AL2 has been oriented to use one main inbound gate close to the new identified storage area. For instance, in the previous flowchart, material was moved from external storage WX3 to WZ10, via either the right and the left gate, causing a longer travelling distance in total. On the contrary, in the new material flow, the overall travelled distance is assumed to be shortened for the A and B components, which are more frequently replenished, following the theory provided by Jonsson (2008).

The new proposed layout is assumed to decrease the travel distance for forklift drivers/pickers, which are assumed to be the main contributor to the amount of kilometres travelled within the plant, but will increase the walking distance of assemblers (who contribute to a lower level of the total distance covered). On the other hand, as already explained, picking time and distance walked of assemblers are assumed to be reduced since the picking process carried out by such operator is conducted with a wagon via one single tour for A and B components and one for the remaining components. In this way, the main part of the fourteen runs needed to collect the required items aimed for the assembler order, shown in Table 7, will be substituted by a few picking tours, as shown by Figure 41. Further time is assumed to be saved during the assemblage, since material used in the assembly process is collected directly from the wagon standing close to the assembly table, so that assemblers do not have to continuously move around the storage facilities within AL2 during the process itself, as in the current situation. These considerations are well explained in Figure 41, showing material movement conducted by assemblers.

![Diagram](image_url)

**Figure 41:** The new picking routes for assembler (Dagberg, Thorén, Tozzi & Velichkov, 2013)
5.3.3 Simulation of distance covered and time spent with an ABC approach

As previously highlighted in paragraph 5.3.2, the new layout is assumed to have a positive effect on distance and time parameters for most of the studied component categories from a replenishment run point of view. By applying the same calculation methodology used in paragraph 5.2.2.1, using the old data over number of replenishment runs conducted by forklift drivers/pickers during 2012, and multiply those figures with a new estimated distance and time per replenishment run (as a result of introducing storage NEW12 respecting that A and B items have new tours while C items will keep more or less the same as the current situation) generates the facts presented in Figure 42, 43, 44 and 45.

![Total time spent (h) for the New layout](image)

**Figure 42:** Total time spent (h) for the New layout (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Figure 43: Total distance covered (Km) new layout (Dagberg, Thorén, Tozzi & Velichkov, 2013)

Figure 44: Simulated percentage distribution of kilometres covered on a yearly basis (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Further on, simulating replenishment runs within the new storage layout indicates that total distance covered (in kilometres) and total time spent (in hours) by forklift drivers/pickers to replenish the aluminium profiles will require approximately 2000 hours and 90 km, in comparison with approximately 5700 hours and 280 km actual required during 2012. This data are shown in Table 15 and Table 16. This category is positioned in the top among the others both regarding time spent and distance covered, and are also representing the largest savings for both parameters if the new layout should be introduced. Aluminium frameworks represent the second largest category from a saving point of view with a decrease of in total 94 km and 1210 hours on a yearly basis with the new layout taken in consideration.

Continuing the analysis into details and focusing on categories that seems to be negatively affected or having an unchanged situation in terms of an increase in time and distance required on a simulated yearly basis, pinpoints five categories as follow:
1. **Fans** (A items)
   As this category will be produced only when a customer order is received and will not be treated as an SKU in the sense of being stored in storage NEW12, motivates that the replenishment run will be kept as per today.

2. **Panel kit** (A and B items)
   As this category will be produced only when a customer order is received and will not be treated as an SKU in the sense of being stored in storage NEW12, motivates that the replenishment run will be kept as per today with the exception that the WIP area is moved closer to the Assembly line 2.

3. **Lamp and electronic device for lamps** (B items)
   Those two categories will be negatively affected as they will be replenished from electronic production (9b) to the NEW12 storage, requiring a longer distance.

4. **Inspection windows** (B item)
   This category is a B item and should in the proposed logic be moved and stored in NEW12. Due to the fact that such items is used during the separated production process of doors, conducted by the assembler himself during the assembly process (spaghetti line C7 in table 7), motivates that the windows could be seen as semi-finished items and therefore stored close to the actual production activity, i.e. in storage area WZ10C3.

5. **Corner connection devices (Plastic)** (C item)
   As this is a pure C component, it will be stored in the area close the assembly line, i.e. keeping the same replenishment run as per the current situation.

<table>
<thead>
<tr>
<th>Component category</th>
<th>Old (km)</th>
<th>New (km)</th>
<th>Delta</th>
<th>Delta in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile (Aluminum)</td>
<td>279.1</td>
<td>90.5</td>
<td>-188.7</td>
<td>-67.6%</td>
</tr>
<tr>
<td>Fan</td>
<td>77.9</td>
<td>77.9</td>
<td>0.0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Air dumper</td>
<td>100.3</td>
<td>71.6</td>
<td>-28.7</td>
<td>-28.6%</td>
</tr>
<tr>
<td>Filter montage</td>
<td>82.5</td>
<td>55.5</td>
<td>-27.0</td>
<td>-27.8%</td>
</tr>
<tr>
<td>Connection panel (Fan)</td>
<td>66.8</td>
<td>47.2</td>
<td>-19.6</td>
<td>-29.2%</td>
</tr>
<tr>
<td>Aluminum framework</td>
<td>136.0</td>
<td>41.9</td>
<td>-94.1</td>
<td>-69.2%</td>
</tr>
<tr>
<td>Panel kit</td>
<td>38.8</td>
<td>38.6</td>
<td>0.0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Aluminum profile (Fan)</td>
<td>13.0</td>
<td>4.7</td>
<td>-8.3</td>
<td>-64.2%</td>
</tr>
<tr>
<td>Corner connection device (with rivet nut)</td>
<td>4.3</td>
<td>3.2</td>
<td>-1.1</td>
<td>-26.3%</td>
</tr>
<tr>
<td>Corner connection device (Red painted)</td>
<td>3.4</td>
<td>2.5</td>
<td>-0.9</td>
<td>-26.3%</td>
</tr>
<tr>
<td>Corner connection device (Plastic)</td>
<td>1.9</td>
<td>1.9</td>
<td>0.0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Lamp</td>
<td>0.6</td>
<td>1.4</td>
<td>0.8</td>
<td>148.6%</td>
</tr>
<tr>
<td>Electronic device for lamp</td>
<td>0.5</td>
<td>1.4</td>
<td>0.8</td>
<td>148.6%</td>
</tr>
<tr>
<td>Inspection window</td>
<td>1.1</td>
<td>1.1</td>
<td>0.0</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

**Table 16** Comparison between the old and the new layout with the kilometres in focus
(Dagberg, Thorén, Tozzi & Velichkov, 2013)
<table>
<thead>
<tr>
<th>Component category</th>
<th>Old (h)</th>
<th>New (h)</th>
<th>Delta</th>
<th>Delta in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile (Aluminum)</td>
<td>5717,2</td>
<td>1943,9</td>
<td>-3773,3</td>
<td>-66,0%</td>
</tr>
<tr>
<td>Fan</td>
<td>978,5</td>
<td>978,5</td>
<td>0</td>
<td>0,0%</td>
</tr>
<tr>
<td>Air dumper</td>
<td>967,4</td>
<td>716,1</td>
<td>-251,3</td>
<td>-21,1%</td>
</tr>
<tr>
<td>Filter montage</td>
<td>1033,6</td>
<td>627,9</td>
<td>-405,7</td>
<td>-39,3%</td>
</tr>
<tr>
<td>Aluminum framework</td>
<td>1753,8</td>
<td>543,2</td>
<td>-1210,6</td>
<td>-69,0%</td>
</tr>
<tr>
<td>Panel kit</td>
<td>494,0</td>
<td>494,0</td>
<td>0</td>
<td>0,0%</td>
</tr>
<tr>
<td>Connection panel (Fan)</td>
<td>684,3</td>
<td>483,8</td>
<td>-200,5</td>
<td>-29,3%</td>
</tr>
<tr>
<td>Aluminum profile (Fan)</td>
<td>266,2</td>
<td>99,4</td>
<td>-166,8</td>
<td>-62,6%</td>
</tr>
<tr>
<td>Corner connection device (with rivet nut)</td>
<td>44,2</td>
<td>32,8</td>
<td>-11,4</td>
<td>-25,9%</td>
</tr>
<tr>
<td>Corner connection device (Red painted)</td>
<td>34,8</td>
<td>25,8</td>
<td>-9,0</td>
<td>-25,9%</td>
</tr>
<tr>
<td>Corner connection device (Plastic)</td>
<td>19,3</td>
<td>19,3</td>
<td>0</td>
<td>0,0%</td>
</tr>
<tr>
<td>Lamp</td>
<td>5,3</td>
<td>15,5</td>
<td>10,2</td>
<td>190,0%</td>
</tr>
<tr>
<td>Electronic device for lamp</td>
<td>5,3</td>
<td>15,5</td>
<td>10,1</td>
<td>190,0%</td>
</tr>
<tr>
<td>Inspection window</td>
<td>15,3</td>
<td>15,3</td>
<td>0</td>
<td>0,0%</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>11959</strong></td>
<td><strong>6011</strong></td>
<td><strong>-5948</strong></td>
<td><strong>-49,7%</strong></td>
</tr>
</tbody>
</table>

**Table 17**: Comparison between the old and the new layout with the time in focus  
(Dagberg, Thorén, Tozzi & Velichkov, 2013)
6. Conclusion

The aim of this chapter is to give an answer to research questions of the present thesis. The conclusion shows how IV Produkt’s order to delivery process, from material supply functions to AL2, is built up today, and defines how this process should be improved in order to minimize the risk of material shortage and waiting times, including a proposal regarding a new storage layout. A summary of the conclusion chapter is shown in Figure 47.

RQ1) How is the order to delivery process, from material supply functions to the Assembly line 2, at IV Produkt built up today?

Combining the theoretical framework for the thesis with the empirical data collected from the studied company, an analysis of the current order to delivery process, from the material supply functions to the Assembly line 2, was provided. In this way, it was possible to answer the first research question of the thesis. Studying current material and information flows, a specific sequence of activities which are repeated time after time can be identified. In such sequence, it is possible to note that material movement within the plant is based and triggered by a complex system of communication and information sharing, involving an identified group of members within the company. The process in question is built up as shown in Figure 46.

Figure 46: The order to delivery process, from material supply functions to the Assembly line 2
(Dagberg, Thorén, Tozzi & Velichkov, 2013)
As it is possible to note from the figure, the process is triggered by a customer order, which is entered by the master planner department into the IFS system as a continuous daily work. On the basis of customer’s requirements, master planners make a general plan over the production, which is communicated via the IFS system to the different manufacturing departments (panels, fans) and the Assembly line 2, with the exception of the aluminium profiles department that receives the data via a card system. The plan provides each department with information about the quantity of material to be produced and the related deadlines. Subsequently, managers at each specific department structure a weekly manufacturing list, detailing the tasks to be carried out by subordinated employees. Supply activities are then carried out by forklifts drivers/pickers which move the required material from external or internal warehouses to the storage area aimed for the Assembly line 2. Finally, the studied order to delivery process ends when all the components needed to complete the unit ordered by the customer are moved by assemblers from the storage facilities aimed for the line to the assembly table.

Observing the studied process from an external point of view, gives the impression that if material and information would perfectly follow this structure, would IV Produkt be able to operate at a higher efficient level. On the contrary, analysing in depth how the studied order to delivery process is built up today, it is possible to highlight several kind of weaknesses originated by a lack in the communication and information sharing, which consequently leads to unnecessary material movements, lack in time coordination between suppliers of AL2 and assemblers, inefficient picking activities and incorrect replenishment policies. Weaknesses of the current order to delivery process can also be highlighted from a storage layout point of view.

**RQ2) How can the order to delivery process of raw material and semi-finished products, between material supply functions and the Assembly line 2, be improved in order to minimize the risk of material shortage and waiting times?**

Clear conclusions can be drawn in order to improve the weaknesses above described with the aim to give an answer to the second research question. A first main proposal is to extend the use of the data system IFS. By using IFS in its fully potential, the firm will improve the communication and information sharing not only in the studied area, but also within the whole plant. Moreover, the company will be able to spread all the needed information throughout the whole organization and make it possible for all actors to carry out their activities on time. To be able to extend the use of IFS system, the authors of the thesis argue that IV Produkt has to educate the personnel on how to use the system in their daily work, which will permit the company to gain several advantages in terms of an increased flexibility and a higher responsiveness to customer demand.
Further on, a higher level of information sharing will be particularly beneficial for the firm, since it will encourage the involvement of employees in company’s decision and therefore their motivation to contribute to business results will increase. In particular, the internal data system should be used to communicate data regarding the sequence of picking activities that forklift drivers/pickers need to carry out. By determining a priority among different activities, will result in a reduction of material shortage and waiting time. Managers should also use the IFS system to collect information needed to indicate standard physical paths that forklift drivers/pickers and assemblers should follow within the plant, in order to collect the required material. A standardization of operators’ movements will lead to a reduction of waste, in terms of cost and time, connected to unnecessary movements of material. Extra movements could also be limited by communicating information about type and quantity of aluminium profiles, which are needed to be produced and replenished, to employees at the profile department, in order to avoid the current unneeded replenishment runs. In addition, considering the present issue regarding the different working speed between forklifts drivers/pickers and assemblers, managers responsible for those areas should improve their communication, for example via more frequent meetings, in order to reach a time coordination between the activities carried out by the related subordinated employees. In overall, improvements in information flow will lead to a positive spin off effect, resulting in a more efficient material flow. The outcome of those proposed actions will, according to the authors of the thesis, positively affect the studied order to delivery process, gaining efficiency by minimizing the risk of material shortage and waiting times.

The ABC classification methodology is not used by the company today. With that standpoint, a general conclusion can be drawn in terms of that IV Produkt will find several advantages via the implementation of this classification logic, applied to their component portfolio. The authors of the thesis also conclude, though outside the scope of the thesis, that such calculation tool might even be applied to other areas within the company. Exemplified areas are finished product portfolio, customer portfolio but also raw materials which will provide the purchasing department a better and more precise purchasing planning strategy. Above presented conclusion and clear statement finds their motivation based on the analytical results which are supported by the theoretical framework applied to empirical findings.

The implementation and simulation of the ABC logic in the present studied area, provides a clear picture over component segments within the case company. In other words, which component category belongs to which type of class. As stated by previous studies, this logic will help the user to apply an appropriate strategy for each type of item-class, suitable for the actual area of appliance and targeted results. As a concluding remark, analytical findings based on theoretical
framework showed that this classification is applicable for the actual area of study as A and B items (representing the largest contribution to total replenishment parameters) as well as C items were identified with a trustful hit rate. The result has led to a visualisation of items which was further on used as key inputs to the answer of research question three.

The findings presented in the analytical chapter highlights that a Kanban approach can be introduced as a proposal to improve the ineffective replenishment policy of the bulk material and other specific typologies of items. By implementing this method in accordance with given guidelines, IV Produkt will gain a more efficient control over the quantity of bulk material consumed by Assembly line 2. In fact, the company will get information about the exact stock level of different components located in the internal storing area, which will reduce the need of re-ordering new bulk items, resulting in a decrease of unnecessary movements of material. Moreover, the use of a Kanban will lower the level of capital tied-up in the inventory, due to the reduced quantity of bulk material kept in store. On the basis of these considerations, this approach will contribute to the minimization of material shortage and waiting times.

**RQ3)** How can the physical storage of raw material and semi-finished products be structured within the studied area, in order to support RQ2?

One of the main targets pointed out by the management team within IV Produkt, is to provide their customer segment with a wide range of products and customer designed solutions. This approach implies a need of a high flexibility and a detailed control of external and internal delivery precision, as well as a high delivery reliability. A wide product range generates a larger amount of different types of components and stresses, for the studied company, a need of a well implemented material supply structure. The analysis conducted in the present thesis showed a number of areas for improvements, among them, a non-efficient nor value adding material handling process. These non-efficient processes were seen as a result of numerous material storage areas spread out in different locations within the production facility.

The authors of the thesis argued that the case company should firstly introduce an ABC classification for all their components. The ABC logic should thereafter work as a guideline for the reconstruction of the storage layout in terms of separating high and medium high frequent items from low frequent replenished items. The company will, through this new approach, gain significant benefits in terms of large time savings, as well as a remarkable decrease of distance travelled by forklift drivers/pickers and employees at aluminium profile on a yearly basis. By introducing this logic, in combination with the physical introduction of the storage area “NEW12”, it was evidently proven in the analytical paragraph that the case company could reach,
in total on a yearly basis, a saving equal to 49.7% of man hours. In other words, nearly halve the

time required by these operators to conduct the replenishment of components to the assembly

line. The same statement can also be applied for travelled distance required to conduct these

operations. By implementing the new storage layout in terms of structuring needed components

would lead to, in total on a yearly basis, a saving equal to 45.0% of kilometres walked or driven

by these operators. The authors of the thesis also conclude that, by locating items in a fewer

number of storage areas, should lead to waste reduction in terms of minimizing time spent by

operators searching for missing material, an activity which was commonly present and detected
during the empirical study. The conclusion is, less areas to store the material in, leads to fewer

areas to be search through, if a component is missing.

Furthermore, the suggested U-shaped layout aimed for the storage area NEW12 is also concluded
to generate positive effects both for forklift drivers/pickers as well as for assembly line personnel.
Firstly, the location and the physical layout will improve the replenishment handling as A
components are located closest to the main entrance viewed from supply functions point of view,

leading to shorter replenishment runs. The concluding idea is also to bring in a safety perspective
as by using the proposed layout will not eliminate, but minimize forklift movements close to
pedestrians, i.e. assemblers preparing assembly orders. The forklift will via the new layout be

naturally steered to move outside the storage area, leading to a safe area within the new storage
zone. On the other hand, risk for collision is still present in the walking path surrounding the
storage area. From an assembler point of view, the U-shape will ease the picking/preparing
activity of assembly orders, as all needed material can be picked in one single tour. This leads to
the conclusion that the previous “star shaped” picking process conducted by the assembler,
presented via the spaghetti analysis, could be seen as straighten out into just a few picking tours
which are more straight forward and flow oriented.

The identified improvement in terms of savings related to reduction of time spent and distance
covered while carrying out replenishment activities, will indirectly contribute to the minimization
of the risk of material shortage and waiting times. In fact, savings related to those specific wastes
can be transformed into a higher availability of forklift drivers/pickers in supplying material to
assembly line. In other terms, by achieving a higher efficiency in terms of picking activities will

generate a positive effect for the customers (the assembly line) leading to a general improvement
of the studied order to delivery process.
Figure 47: Summary of the conclusion (Dagberg, Thoren, Tozzi & Velichkov, 2013)
7. Reflections

The purpose of this chapter is to highlight reflections made by the authors about the obtained results, as well as underline main limitations which might have affected the result of present study. Moreover, the chapter is ended defining areas for improvements and suggestion for further research.

Considering the scope of the thesis, the initial area of study was strictly connected with the internal material flow within the selected company. Further on, during the actual progress of the study, the authors found the need to analyse additional issues and to include further elements to be able to obtain the desired result, indicating that limitation of the thesis were not properly set from the start of the project. With this knowledge in mind, the authors have strived to complete a deep analysis as possible, given the actual limited time frame.

With regard to the collection of the empirical data, a main limitation of the present thesis is related to the limited research area which have been analysed. The present thesis is considering only part of the entire order to delivery process and only one out of three assembly lines, with the intention to enable a generalization of the finding and an extension of the results to similar areas within the plant. However, the authors of the thesis are aware of the fact that a higher validity and accuracy of data could have been obtained if the overall process would have been studied.

Moreover, an additional limit is related to the sample size, in terms of participants to surveys involved in the collection of data. Although different typologies of workers have been interviewed, a deepened analysis should require the study of a higher number of “voices”, comparing the range of employees which have answered elaborated questionnaires.

Therefore, a main suggestion for further investigations and research about the considered area of study, is to enlarge the scope for the research, focusing on the studied process from a wider perspective and involving a higher number of participants in the data collection. Through this approach, a larger source of data could be gathered and elaborated, resulting in a more accurate and reliable result.
8. Action plan

The aim of this chapter is to provide the company with useful suggestions on how to practically implement the proposed actions needed to improve the analysed area of study.

Implementation plan for the development of the studied order to delivery process

The implementation plan is developed in order to implement highlighted improvement areas with the aim to improve the current order to delivery process within IV Produkt. The plan, which is visualized in Table 17, is divided into four main focus areas covering 1) Expand the use of the IFS system & Information sharing activities 2) ABC-classification 3) Implementation of Kanban and 4) New storage layout, which can be seen as main activities. Each activity contains several actions that have to be carried out in a specific sequence following the PDCA methodology (Plan, Do, Check and Act). In details, the schedule indicates from the left, the specific focus area grouping all actions, titled a P-D depending on sort of action in the time sequence, belonging to that activity. Furthermore, a manager at the plant has been assigned the responsibility for each action in terms of leading the work which has to be carried out according to the time schedule detailing time windows, audits and milestones.
Table 18: Action Plan for the development of the studied process (Dagberg, Thorén, Tozzi & Velichkov, 2013)
Focus area 1 (F1)  Expand the use of the IFS system & Information sharing activities

**Plan:** As the IFS system is planned to be extended into new areas and departments within the firm, points out the need of education among employees who will be affected by this system change. The HR-manager is responsible for planning education activities accordingly.

**Plan:** The production manager is given the responsibility to plan and create a schedule for the new meeting structure, which is requested by the employees with the aim to increase the information sharing function.

**Plan:** The main idea is to introduce the use of the IFS system into new areas and functions within the company. This activity is aimed for evaluating available IFS modules in order to understand their potential in comparison to actual needs, and by that indicating eventually investment needs. The IT-manager is responsible for this evaluation.

**DO:** The HR-manager is responsible for the actual training sessions in accordance with the plan.

**DO:** IT-manager is responsible for the Go-live of IT modifications according to the plan.

**Check x 2:** Two types of questioners are planned to be launched with the purpose to gather feedback and standpoints from employees and managers who have been involved in the new meeting structure, as well as users of new IT functions. The HR-manager is responsible for those actions.

**Check:** The IT-manager is pointed out as responsible for measuring the actual performance of the new IT modification in accordance with system specifications.

**Act:** Responsible manager has to take corrective actions if any negative deltas or critical errors are found during the check phase.

Focus area 2 (F2)  ABC-Classification

**Plan:** The first plan action will be performed by the production manager in order to calculate the ABC class, using up-to-date data, for all items produced and supplied to the assembly line.

**Plan:** The IT-manager is responsible for the planning and preparation of needed configurations with the target to introduce the ABC-logic into the IFS system. The purpose with an IT supported function is to minimize the manual work linked to calculation activates, and to provide updated data upon request, but also to enable an expansion into other areas when applicable.
**DO:** Launch the calculation set-up in the IFS. Responsible manager is the IT-manager.

**Check:** The production manager is responsible to measure and evaluate IFS-ABC data versus manual calculation methods in order to find out if any calculation errors are present, but also to evaluate if calculated classes correspond to the actual live environment.

**Act:** Responsible manager has to take corrective actions if any negative deltas or critical errors are found during the check phase.

**Act:** The production manager is finally responsible to expand the ABC-logic to other areas/function within the plant when applicable.

**Focus area 3 (F3) Implementation of Kanban**

**Plan:** Several plan actions have to be carried out before a Kanban logic can be implemented into the studied area. One of those actions has to be carried out by the production manager in terms of calculating all needed data (for example replenishment lead-times, batch sizes per component respecting the lead-times etc.) which will be used as input during the design of the Kanban flow.

**Plan:** The shop-floor manager is responsible to define the physical set-up for the Kanban flow.

**Plan:** The shop-floor manager is responsible to plan and create purchase requisitions for boxes/pallets/cards and other items needed to make the flow work.

**Plan:** Key Point Indicators (KPIs) have to be defined by the production manager to be used for measuring the Kanban performance (number of out of stock situations within the flow, number of interrupted replenishment runs etc.).

**DO:** Implement the Kanban logic on the bulk material flow. Responsible for the action is the shop-floor manager.

**Check:** The shop-floor manager is responsible to measure given KPIs for the flow.

**Act:** Responsible manager has to take corrective actions if any negative deltas or critical errors are found during the check phase.

**Act:** The shop-floor manager is responsible to implement/expand the Kanaban logic to other component flows indicated in the study (inspection windows, corner connection devices etc.).
Focus area 4 (F4) New storage layout

Plan: One of the main plan actions, which has to be carried out by the shop-floor manager, is to calculate the physical area for the “NEW12” storing zone in terms of square meters and racks/shelves needed to store all A & B items.

Plan: The production manager is responsible for planning and preparing investments in racks/shelves respecting the calculation provided by the shop-floor manager.

Plan: A new and official map/chart over “NEW12” has to be developed by the production manager.

Plan: The shop-floor manager is responsible to plan and define standard routes which forklift drivers/pickers have to follow during their replenishment runs.

Plan: The shop-floor manager is responsible for defining checkpoints to be used for measuring the actual use of the standardized routes i.e. to control if they are respected by the users.

DO: Go-live in terms of physical construction of the new storage area “NEW12”. The shop-floor manager is responsible for the action.

DO: The Go-live in terms of implementing new replenishment routes will be controlled by the production manager.

Check: Follow-up and evaluate that all A & B items are physically stored as planned. The action has to be carried out by the shop-floor manager.

Check: Measure if new replenishment routes are respected by the operators. The action has to be carried out by the shop-floor manager.

Act: Responsible manager has to take corrective actions if any negative deltas or critical errors are found during the check phase.
9. Reference list

9.1 Literature


### 9.2 Scientific articles


~ 131 ~


9.3 Verbal sources


Johansson, A. *Manager for Assembly line 2, IV Produkt* [Interview] (2 May 2013).


9.4 Websites


10. List of Figures

**Figure 1:** IV Produkt’s Supply Chain (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 8

**Figure 2:** Internal perspective of the logistic system. The own company is the starting point (Jonsson, 2008, p. 39) .......................................................... 9

**Figure 3:** Material flow within IV Produkt (from inbound flow to assembly line), highlighting the order to delivery process (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 12

**Figure 4:** Disposition of the thesis (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 13

**Figure 5:** Model of the thesis structure (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 14

**Figure 6:** Framework of the theory chapter (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 26

**Figure 7:** The information flow of order from customer to supplier (Mattsson, 1999, p. 204) .......................................................... 28

**Figure 8:** Push and pull approaches in the management of material flow (Jonsson, 2008, p. 269)  .......................................................... 30

**Figure 9:** Process flowchart (Chase, et al., 2006, p. 161) (Jonsson, 2008, p. 113) .......................................................... 32

**Figure 10:** Layout Flow Chart (Gitlow, et al., 1995, p. 61) .......................................................... 33

**Figure 11:** Layout plant for a printing company before (A) and after (B) a Spaghetti diagram analysis (Allen, 2010, p. 130) .......................................................... 34

**Figure 12:** The operation of the single-card Kanban system of pull control (Slack, et al., 2004, p. 534) .......................................................... 38

**Figure 13:** Use of Kanban card for transfer between stocks (Jonsson, 2008, p. 275) .......................................................... 39

**Figure 14:** ABC analysis based on the Pareto principle (Heizer & Render, 2004) .......................................................... 43

**Figure 15:** Examples of different storage layout using a Class-based method (Chen, et al., 2010, p. 72; de Koster, et al., 2007, p. 490) .......................................................... 46

**Figure 16:** Mapping of the entire order to delivery process (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 51

**Figure 17:** Material flowchart at IV Produkt (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 53

**Figure 18:** All the different modules produced on the AL2 (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 54

**Figure 19:** Picture of 150 unit (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 55
Figure 20: Spaghetti diagram, Flow A and B (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................... 61
Figure 21: Spaghetti diagram, Flow C (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................... 66
Figure 22: Total number of component types within each component category (Dagberg, Thorén, Tozzi & Velichkov, 2013) ................................................................. 69
Figure 23: Total number of units consumed per component category .................................................. 69
Figure 24: Total number of units consumed per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013) ......................................................................................... 70
Figure 25: Distribution of the consumption (%) (Dagberg, Thorén, Tozzi, Velichkov, 2013) .............. 70
Figure 26: Framework of the analysis chapter (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......... 77
Figure 27: Process map of the studied order to delivery process ...................................................... 80
Figure 28: ABC classification of components based on replenishment runs (Dagberg, Thorén, Tozzi & Velichkov, 2013) ................................................................................. 96
Figure 29: A-Items per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......... 97
Figure 30: B-Items per component category (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......... 98
Figure 31: Total number of components classified as C items (Dagberg, Thoren, Tozzi & Velichkov, 2013) ........................................................................................................... 99
Figure 32: Total distance covered (Km) 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013) ....... 100
Figure 33: Total time spent (h) 2012 (Dagberg, Thoren, Tozzi & Velichkov, 2013) .................. 100
Figure 34: Percentage distribution of kilometres covered during 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013) .................................................................................. 101
Figure 35: Percentage distribution of total number of hours spent during 2012 (Dagberg, Thorén, Tozzi & Velichkov, 2013) ........................................................................ 101
Figure 36: Summarized scheme of paragraph 5.2 (Dagberg, Thoren, Tozzi & Velichkov, 2013) .... 103
Figure 37: The new suggested layout construction (Dagberg, Thoren, Tozzi & Velichkov, 2013) .... 105
Figure 38: Layout of the new to storage (Dagberg, Thorén, Tozzi & Velichkov, 2013) .............. 106
Figure 39: New layout for the storage surrounding Assembly line 2 (Dagberg, Thorén, Tozzi & Velichkov, 2013) ......................................................................................... 108
Figure 40: Material flowchart within the new storage layout (Dagberg, Thoren, Tozzi & Velichkov, 2013) ................................................................. 109
Figure 41: The new picking routs for assembler (Dagberg, Thorén, Tozzi & Velichkov, 2013) ....... 110
Figure 42: Total time spent (h) for the New layout (Dagberg, Thorén, Tozzi & Velichkov, 2013) .... 111
Figure 43: Total distance covered (Km) new layout (Dagberg, Thorén, Tozzi & Velichkov, 2013) .... 112
Figure 44: Simulated percentage distribution of kilometres covered on a yearly basis (Dagberg, Thorén, Tozzi & Velichkov, 2013) ........................................................................ 112
Figure 45: Simulated percentage distribution of hours spent on a yearly basis (Dagberg, Thorén, Tozzi & Velichkov, 2013) .............................................................................. 113
Figure 46: The order to delivery process, from material supply functions to the Assembly line 2 (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 116
Figure 47: Summary of the conclusion (Dagberg, Thoren, Tozzi & Velichkov, 2013) .................. 121

~ 135 ~
11. List of Tables

Table 1: The time plan (Dagberg, Thoren, Tozzi & Velichkov, 2013) ......................................................... 15
Table 2: Overview of the participated employees in IV Produkt (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................... 23
Table 4: Components involved in the studied order to delivery process (Dagberg, Thorén, Tozzi & Velichkov, 2013) ........................................................................................................... 55
Table 5: Table of measurement, Flow A (Dagberg, Thorén, Tozzi & Velichkov, 2013) ........................................ 56
Table 6: Table of measurement, Flow B (Dagberg, Thorén, Tozzi & Velichkov, 2013) ........................................ 57
Table 7: Table of measurements, Flow C (Dagberg, Thorén, Tozzi & Velichkov, 2013) ................................. 62
Table 8: Database regarding components used by the assembly line (Dagberg, Thorén, Tozzi & Velichkov, 2013) ...................................................................................................................... 67
Table 9: Computing keys used to measure number of replenishment runs (Dagberg, Thorén, Tozzi & Velichkov, 2013) .............................................................................................................. 68
Table 10: Personal information about the respondents (Dagberg, Thorén, Tozzi & Velichkov, 2013) .... 71
Table 11: Personal information about the respondent (Dagberg, Thorén, Tozzi & Velichkov, 2013) .... 74
Table 12: Total number of components classified as A items (Dagberg, Thorén, Tozzi & Velichkov, 2013) ................................................................................................................................. 97
Table 13: Total number of components classified as B items (Dagberg, Thorén, Tozzi & Velichkov, 2013) ................................................................................................................................. 98
Table 14: C-Items per component category (Dagberg, Thoren, Tozzi & Velichkov, 2013) ......................... 99
Table 15 Comparison between the old and the new layout with the kilometres in focus (Dagberg, Thorén, Tozzi & Velichkov, 2013) ....................................................................................... 114
Table 16: Comparison between the old and the new layout with the time in focus (Dagberg, Thorén, Tozzi & Velichkov, 2013) ...................................................................................................... 115
Table 17: Action Plan for the development of the studied process (Dagberg, Thorén, Tozzi & Velichkov, 2013) .......................................................................................................................... 124

~ 136 ~
Appendices

Appendix 1 Questionnaire for operators working at Assembly line 2

Du tillhör avdelning/område: ________________________________

Kön:  

- Kvinna  
- Man

Ålder:  

- 16-25år  
- 26-35år  
- 36-45år  
- 46-55år  
- >56år

Hur länge har du arbetat på IV Produkt?  

- 0-1 år  
- 2-4 år  
- 5-10 år  
- >11 år

Hur länge har du arbetat på din nuvarande tjänst?  

- 0-1 år  
- 2-4 år  
- > 5 år

Har du arbetserfarenhet från annan avdelning eller från annat ansvarsområde inom företaget?  

- Ja  
- Nej

1a. Vilka är dina huvudsakliga arbetsuppgifter?  

______________________________________________________

______________________________________________________

______________________________________________________

1b. För att kunna utföra dina arbetsuppgifter eller en specifik arbetssekvens, behöver du då fysiskt förflytta dig till en annan avdelning eller annat område utanför ditt ordinarie arbetsområde?  

- Om Ja,  
- Ja  
- Nej

1c. Till vilken avdelning/avdelningar eller vilket område/områden?  

______________________________________________________

______________________________________________________

1d. Hur ofta under ett arbetspass behöver du göra denna/dessa förflyttningar?  

- 1-3ggr/pass  
- 4-6ggr/pass  
- 7-9ggr/pass  
- >10ggr/pass

~ 137 ~
1e. Hur förflyttar du dig mellan avdelning/avdelningar eller område/områden?

<table>
<thead>
<tr>
<th>Till fots</th>
<th>Sparkcykel</th>
<th>Truck</th>
<th>Annat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

1f. Ungerfär hur många minuter per arbetspass spenderar du på att genomföra dessa förflyttningar?

<table>
<thead>
<tr>
<th>1min – 10min</th>
<th>11min-30min</th>
<th>31-60min</th>
<th>1-2 timmar</th>
<th>2-4 timmar</th>
<th>&gt; 4 timmar</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1g. Vad anser du är bra idag gällande den fysiska arbetsmiljön?
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

1h. Vad anser du kan förbättras gällande den fysiska arbetsmiljön?
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

2a. Behöver du hämta/plocka artiklar eller komponenter utanför ditt arbetsområde för att utföra dina arbetsuppgifter? (Exempel: du arbetar som montör och behöver gå till kapen eller lager utomhus för att hämta aluminiumprofiler eller andra artiklar?)

Om Ja,

<table>
<thead>
<tr>
<th>Ja</th>
<th>Nej</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

2b. Till vilken avdelning/avdelningar eller vilket område/områden?
_____________________________________________________________________________________

2c. Hur ofta under ett arbetspass behöver du hämta/plocka artiklar eller komponenter utanför ditt arbetsområde?

<table>
<thead>
<tr>
<th>1-3ggr/pass</th>
<th>4-6ggr/pass</th>
<th>7-9ggr/pass</th>
<th>&gt;10ggr/pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2d. Hur hämtar/plockar du dessa artiklar eller komponenter?

<table>
<thead>
<tr>
<th>Till fots</th>
<th>Truck</th>
<th>Sparkcykel</th>
<th>Annat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

2e. Ungefär hur mycket tid per arbetspass spenderar du på att genomföra dessa förflyttningar?

<table>
<thead>
<tr>
<th>1min – 10min</th>
<th>11min-30min</th>
<th>31-60min</th>
<th>1-2 timmar</th>
<th>2-4 timmar</th>
<th>&gt; 4 timmar</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2f. Vad anser du fungerar bra idag gällande dina möjlighet att hämta/plocka artiklar eller komponenter?

_____________________________________________________________________________________

_____________________________________________________________________________________

2g. Vad anser du kan förbättras gällande hämtning/plock av artiklar eller komponenter?

_____________________________________________________________________________________

_____________________________________________________________________________________

3a. Hur bedömer du din kunskap gällande syftet med arbetsuppgifter som utförs av medarbetare inom ditt ansvarsområde? (Ej hur de utförs)

Dålig  Ganska bra  Bra  Mycket bra

☐  ☐  ☐  ☐

3b. Hur bedömer du din kunskap gällande syftet med arbetsuppgifter som utförs av medarbetare utanför ditt ansvarsområde? (Ej hur de utförs, utan syfte och funktion med aktiviteter innan och efter ditt ansvarsområde)

Dålig  Ganska bra  Bra  Mycket bra

☐  ☐  ☐  ☐

3c. Har skulle du bedöma din kunskap om materialflödet inom företaget? (från godsmottagning av artiklar till leverans av färdigvara/slutfördom till kund)

Dålig  Ganska bra  Bra  Mycket bra

☐  ☐  ☐  ☐

3d. Om behov finns, vilka aktiviteter anser du kan genomföras för att din kunskap gällande syfte med andra arbetsuppgifter och materialflöden inom företaget skall förbättras?

_____________________________________________________________________________________

_____________________________________________________________________________________

4a. Upplever du att artiklar/komponenter finns tillgängliga på avsedd plats när du behöver dem?

Ja  Nej

☐  ☐

Om NEJ,
4b. Vad anser du är orsaken till detta?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

4c. Vilka artiklar eller komponenter anser du är mest drabbade av denna störning?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

4d. Hur agerar du om artikeln eller komponenten inte finns tillgänglig på avsedd platts?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

4e. Hur lång tid behöver du i genomsnitt vänta på att artikeln eller komponenten skall bli
tillgänglig?

<table>
<thead>
<tr>
<th>1min – 10min</th>
<th>11min-30min</th>
<th>31-60min</th>
<th>1-2 tim</th>
<th>2-4 tim</th>
<th>4-8 tim</th>
<th>&gt; mer än en arbetsdag</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

4f. Anser du att vissa artiklar eller komponenter bör placeras närmare ditt arbetsområde?
Ja Nej

Om JA,

□ □

4g. Vilken eller vilka artiklar berörs?
_________________________________________________________________________
_________________________________________________________________________

4h. Vad anser du är bra idag gällande materialhanteringen?
_________________________________________________________________________
_________________________________________________________________________

4i. Vad anser du kan förbättras gällande materialhanteringen?
_________________________________________________________________________
_________________________________________________________________________

5a. Vilket kommunikationssätt används mest för att sprida och ta del av arbetsrelaterad information?

<table>
<thead>
<tr>
<th>Intranet</th>
<th>Verbalt öga mot öga</th>
<th>Informationstavlor</th>
<th>E-mail</th>
<th>Telefon</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
5b. Hur får du information om när en specifik uppgift skall utföras? (exempelvis påbörja en monteringsorder, hämta en viss artikel etc.)

5c. Om en arbetsuppgift innebär att du skall hämta/plocka en artikel eller komponent, hur genomför du då denna uppgift? Hämtar/plockar du enligt en specifik rut, enligt en plocklista eller i den ordning/följd som du själv anser är bäst?

5d. Anser du att det finns brister i dagens interna kommunikationen, vilket i sin tur leder till att du ej kan genomföra dina arbetsuppgift på bästa sätt?

Ja □ Nej □

Om JA,

5e. Vilken information anser du saknas och vad anser du är orsaken till detta?

5f. Vad anser du fungerar bra idag gällande den intern kommunikation?

5g. Vad anser du kan förbättras gällande den intern kommunikation?
Appendix 2 Questionnaire for operators supplying Assembly line 2

Jag tillhör avdelning/område: ________________________________________________

Kön:       Kvinnan Man
☐       ☐

Ålder:  16-25år  26-35år  36-45år  46-55år  >56år
☐       ☐       ☐       ☐       ☐

Hur länge har du arbetat på IV Produkt?
☐  0-1 år  2-4 år  5-10 år  >11 år

Hur länge har du arbetat på din nuvarande tjänst?
☐  0-1 år  2-4 år  > 5 år

Har du arbetserfarenhet från annan avdelning eller från annat ansvarsområde inom företaget?
Ja  ☐  Nej  ☐

1a. Vilka är dina huvudsakliga arbetsuppgifter?
________________________________________________________________________

OBS: Om du huvudsakligen arbetar som truckförare och ditt ansvarsområde sträcker sig över flera arbetsområden, gå då direkt till fråga 3a.

1b. För att kunna utföra dina arbetsuppgifter eller en specifik arbetssekvens, behöver du då fysiskt förflytta dig till en annan avdelning eller annat område utanför ditt ordinarie arbetsområde?
Ja  ☐  Nej  ☐

Om Ja,

1c. Till vilken avdelning/avdelningar eller vilket område/områden?
________________________________________________________________________

1d. Hur ofta under ett arbetspass behöver du göra denna/dessa förflyttningar?
1-3ggr/pass  4-6ggr/pass  7-9ggr/pass  >10ggr/pass
☐       ☐       ☐       ☐

1e. Hur förflyttar du dig mellan avdelning/avdelningar eller område/områden?
Till fots  Sparkcykel  Truck  Annat
☐       ☐       ☐       ☐

~ 142 ~
1f. Ungerfär hur många minuter per arbetspass spenderar du på att genomföra dessa förflyttningar?

1 min – 10 min    11 min – 30 min    31 min – 60 min    1–2 timmar    2–4 timmar    > 4 timmar

1g. Vad anser du är bra idag gällande den fysiska arbetsmiljön?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

1h. Vad anser du kan förbättras gällande den fysiska arbetsmiljön?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

2a. Behöver du hämta/plocka artiklar eller komponenter utanför ditt arbetsområde för att utföra dina arbetsuppgifter?

Ja    Nej

Om Ja,

2b. Till vilken avdelning/avdelningar eller vilket område/områden?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

2c. Hur ofta under ett arbetspass behöver du hämta/plocka artiklar eller komponenter utanför ditt arbetsområde?

1–3 ggr/pass    4–6 ggr/pass    7–9 ggr/pass    >10 ggr/pass

2d. Hur hämtar/plockar du dessa artiklar eller komponenter?

Till fots    Truck    Sparkcykel    Annat

_____________________________________________________________________________________

2e. Ungerfär hur mycket tid per arbetspass spenderar du på att genomföra dessa förflyttningar?

1 min – 10 min    11 min – 30 min    31 min – 60 min    1–2 timmar    2–4 timmar    > 4 timmar
2f. Vad anser du fungerar bra idag gällande dina möjligheter att hämta/plocka artiklar eller komponenter?
_____________________________________________________________________________________
_____________________________________________________________________________________
2g. Vad anser du kan förbättras gällande hämtning/plock av artiklar eller komponenter?
_____________________________________________________________________________________
_____________________________________________________________________________________
3a. Hur bedömer du din kunskap gällande syftet med arbetsuppgifter som utförs av medarbetare inom ditt ansvarsområde? (Ej hur de utförs)

Dålig         Ganska bra          Bra          Mycket bra

3b. Hur bedömer du din kunskap gällande syftet med arbetsuppgifter som utförs av medarbetare utanför ditt ansvarsområde? (Ej hur de utförs, utan syfte och funktion med aktiviteter innan och efter ditt ansvarsområde)

Dålig         Ganska bra          Bra          Mycket bra

3c. Har skulle du bedöma din kunskap om materialflödet inom företaget? (från godsmottagning av artiklar till leverans av färdigvara/slutprodukt till kund)

Dålig         Ganska bra          Bra          Mycket bra

3d. Om behov finns, vilka aktiviteter anser du kan genomföras för att din kunskap gällande syfte med andra arbetsuppgifter och materialflöden inom företaget skall förbättras?
_____________________________________________________________________________________
_____________________________________________________________________________________

4a. Upplever du att artiklar/komponenter finns tillgängliga på avsedd plats när du behöver dem?
Ja        Nej

Om NEJ, ____________________________________________
4b. Vad anser du är orsaken till detta?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

4c. Vilka artiklar eller komponenter anser du är mest drabbade av denna störning?

________________________________________________________________________
________________________________________________________________________

4d. Hur agerar du om artikeln eller komponenten inte finns tillgänglig på avsedd platts?

________________________________________________________________________
________________________________________________________________________

4e. Hur lång tid behöver du i genomsnitt vänta på att artikeln eller komponenten skall bli tillgänglig?

<table>
<thead>
<tr>
<th></th>
<th>1min – 10min</th>
<th>11min-30min</th>
<th>31-60min</th>
<th>1-2 tim</th>
<th>2-4 tim</th>
<th>4-8 tim</th>
<th>&gt; mer än en arbetsdag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

4f. Anser du att vissa artiklar eller komponenter bör placeras närmare ditt arbetsområde eller specifik produktionslinje?

Ja ☐ Nej ☐

Om JA,
4g. Vilken eller vilka artiklar berörs?

________________________________________________________________________

4h. Vad anser du är bra idag gällande materialhanteringen?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

4i. Vad anser du kan förbättras gällande materialhanteringen?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
5a. Vilket kommunikationssätt används mest för att sprida och ta del av arbetsrelaterad information?

<table>
<thead>
<tr>
<th>Intranet</th>
<th>Verbalt öga mot öga</th>
<th>Informationstavlor</th>
<th>E-mail</th>
<th>Telefon</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

5b. Hur får du information om när en specifik uppgift skall utföras? (exempelvis påbörja en monteringsorder, hämta en viss artikel etc.)

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

5c. Om en arbetsuppgift innebär att du skall hämta/plocka en artikel eller komponent, hur genomför du då denna uppgift? Hämnar/plockar du enligt en specifik ruttn, enligt en plocklista eller i den ordning/följd som du själv anser är bäst?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

5d. Anser du att det finns brister i dagens interna kommunikationen, vilket i sin tur leder till att du ej kan genomföra dina arbetsuppgift på bästa sätt?

Ja [ ] Nej [ ]

Ofta JA,  

5e. Vilken information anser du saknas och vad anser du är orsaken till detta?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

5f. Vad anser du fungerar bra idag gällande den intern kommunikation?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

5g. Vad anser du kan förbättras gällande den intern kommunikation?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
Linnaeus University – a firm focus on quality and competence

On 1 January 2010 Växjö University and the University of Kalmar merged to form Linnaeus University. This new university is the product of a will to improve the quality, enhance the appeal and boost the development potential of teaching and research, at the same time as it plays a prominent role in working closely together with local society. Linnaeus University offers an attractive knowledge environment characterised by high quality and a competitive portfolio of skills.

Linnaeus University is a modern, international university with the emphasis on the desire for knowledge, creative thinking and practical innovations. For us, the focus is on proximity to our students, but also on the world around us and the future ahead.

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