Understanding the Problems in Volume Production and their Connections to Management of New Product Introduction Projects

A Case Study of the Project Management Factors and the Appurtenant Production Effects from Ramp-Up of New Products in Production for Contract Electronics Manufacturing

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Abstract

The ongoing globalization of companies has resulted in a highly competitive business climate where companies have to be cost-effective but still flexible with fast response to customer feedback and present in the international scene. In order to meet the fast paced technological development from the competition and changing demand of the customers, companies focus on creating new products and reducing their time-to-market with an early product launch to gain profits from increased market shares. However, in order to maintain profitability of the new product, it becomes even more important for the company to quickly deploy a full-scale production of the product, also known as the production ramp-up phase.

Despite being known as a major cost driver in new product development projects, production ramp-up is a research area which have yet received sparse attention compared to research on product launch and time-to-market in new product development projects. However, with shorter product life-cycles and higher market competition it has resulted in a need to shorten the length of a new product’s ramp-up time without making any trade-off to the cost-effectiveness of the ramp-up project and the end product's final quality.

The study identifies the common problems in volume production of a contract electronics manufacturer and their sources of disturbances from the new product introduction process. It also identifies the factors influencing the new product introduction process at the company and how these factors are connected different sources of disturbances. To identify these findings, a single case study was designed and performed at Orbit One AB, a contract electronics manufacturer with a low-volume production of products. The data collection course was executed in an iterative manner over a period of four months through interviews, observation and internal documentation and was backed up and analyzed with a literature study. The data collection through interviews was carried out in two separate rounds, where the first round of interviews was focused on identifying the common problems in volume production and the second round was focused on the factors influencing the output from the new product introduction process. The discoveries from the interviews were analyzed together with the other sources of collected data to reach a conclusive analysis.

The results of the study showed that the most common problems in volume production of the company could be traced to six different sources of disturbances: Product, Production System, Design-Production Interface, Quality, Resource Management, and Personnel. The most common problems could also be summarized as: Problems with manufacturability of product; High variation of process performance, Poor correctness of information, Quality issues with products, and High workload on resources. The factors identified in the findings of the study shows that there are multiple and connected factors which affects the final output of the new product introduction process which corroborates with earlier studies and research in the area of production ramp-up. The study did identify two factors which has not been identified by other ramp-up studies, these were: Lack of organizational project culture and customer flexibility.
Acknowledgement

The completion of this thesis marks the end of my studies at Linköping’s University and my masters in the field of Industrial Engineering. Reflecting back on my studies, it has been two eventful years including both personal and professional growth and a lot struggle which finally has paid off.

Working at Orbit One AB and writing this master thesis, in a research field which I personally have a big interest in, has been a very exciting time. Working with the people at the company during the research process has been a great experience which has brought many insightful discussions and personal reflections. I would therefore like to express my gratefulness towards all the people who has supported and helped me throughout the execution of this thesis.

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Thank you all.

Niclas Frost

Karlskrona, June 2016
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<th>Approved Manufacturers List</th>
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<tr>
<td>AOI</td>
<td>Automated Optical Inspection</td>
</tr>
<tr>
<td>CM</td>
<td>Contract Manufacturer</td>
</tr>
<tr>
<td>CEM</td>
<td>Contract Electronics Manufacturer</td>
</tr>
<tr>
<td>DFM</td>
<td>Design for Manufacturing</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
</tr>
<tr>
<td>MLB</td>
<td>Multilayer Board</td>
</tr>
<tr>
<td>NPD</td>
<td>New Product Development</td>
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<td>NPI</td>
<td>New Product Introduction</td>
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<tr>
<td>NRE</td>
<td>Non-Recurring Engineering</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<tr>
<td>TTM</td>
<td>Time-to-Market</td>
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<tr>
<td>TTP</td>
<td>Time-to-Profitability</td>
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<td>TTV</td>
<td>Time-to-Volume</td>
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1 INTRODUCTION

This chapter serves as an introduction for the reader to the industry and the case company Orbit One. It also introduces the topic of volume production for contract manufacturers and how project management handles ramp-up projects for new products in this type of business industry. The problem statement explains the motivation of the thesis which is followed by the scope and research questions. The chapter ends with the limitations of the study and the outline of the report.

1.1 BACKGROUND

Today's globalization of society has influenced the business models of enterprises greatly. In order for companies to stay competitive they have to be cost-effective, flexible with fast response to customer feedback and present in the international scene (Surbier, et al., 2014). In the first half of the twentieth century, companies' supply ruled over customer demand but in today's market company supply is instead pulled by customer demand and plays an important role in what the companies offer. This change on the market together with the fast development of technological advances puts pressure on the companies to innovate their offer to the customer and develop new and better products to capture market shares faster than their competition (Surbier, et al., 2014). Furthermore, new products have become central to companies' profitability, 49% of sales among top performing innovating firms are derived from new products (Di Benedetto, 1999).

The focus on creating new products in order to meet demand and to cope with market competition has led to the implication that companies put great efforts in reducing time-to-market for products, where an early product launch can impact the market share of company greatly due to the competition from other companies in the same industry (Di Benedetto, 1999). As a result, outsourcing has become a common trend among many companies, meaning that companies thus can spend more resources on research and development (R&D) and engineering for innovating their offer and focus on developing new products. This has resulted in a new kind of business model where these companies, commonly called original equipment manufacturers (OEMs), concentrate their core business to R&D, sales and marketing while sub-contracting their production and logistics to other companies. These companies whose sole purpose is to manufacture products for these OEMs are also known as contract manufacturers (CM) or contract electronics manufacturers (CEM) for companies in the electronics industry (Tardif & Nielsen, 2002).

For new product development (NPD), most of the expenses are connected to product launch which is also why a lot of research has been conducted in the area of NPD and the subject of reducing time-to-market for products. Although to achieve profitability for a new product the time it takes to achieve a full scale production for a product, also known as time-to-volume, and acceptable manufacturing levels for volume, cost and quality also has to be considered (Terwiesch, et al., 2001). This time period after product launch to full-scale production, also known as time-to-volume, where the ramp-up of production takes place is known to be a major cost driver (Schuh, et al., 2005) yet research in this area has received little attention compared to research in NPD and time-to-market (Surbier, et al., 2014).
1.2 PROBLEM STATEMENT

The new business model of companies is not the only result of this rapid advancement of technological development, as an effect lifecycles of products have been reduced significantly. Schuh, et. al. (2005) stated that during the last four decades, product lifecycles have been reduced up to 60% while the innovation of new products has increased significantly. In the automotive industry, production ramp-up can be up to six months while time to normal quality after the ramp-up, e.g. reaching steady production, can range from one month up to one year. This time accounts for roughly 10-20% of a car’s lifecycle (Clark & Fujimoto, 1991). For the electronics industry, where a products lifecycle in general is two years or less, this results in that the time portion a product spends in ramp-up in relation to its economic lifecycle can be even larger (Terwiesch, et al., 2001).

Another market factor which has major implications for the ramp-up process in electronics industry is the high erosion if market prices, where the annual price drop can be as high as 50% (Terwiesch, et al., 2001). As the demand is high prior to product launch, customers are willing to pay a premium price for the first entrant on the market. As more competitors enter the market, the prices will fall with an increased decline over time (Terwiesch, et al., 2001).

Moreover, with increased outsourcing ramp-up processes become a complex and challenging issue throughout the connected supply chain. When a product development project nears ramp-up at the OEM it will send a signal for the CEM to ramp-up their processes as well and secure material for production (Terwiesch, et al., 2001; Apilo, 2003; Surbier, et al., 2014). New processes have to be set up prior to the ramp-up and if the maturity of these processes is unverified, events such as slow set-ups, unforeseen bottlenecks, poor design-process fit (manufacturability) are common to arise (Surbier, et al., 2014). Short ramp-ups have several implications for securing material and many problems arise due to the on-time availability and quality of components from external suppliers. In the case study by Terwiesch, Bohn, and Chea (2001) it is recorded that 20 of 55 production line disturbances were related to component issues.

Since both the product and processes are new, the uncertainty of the product’s manufacturability is higher during the ramp-up phase which makes the process even more complex to manage (Meier & Homuth, 2006). In a survey, conducted by the Kühne Institute of the St Gallen University, concerning automobile suppliers 43% of the ramp-ups are economically and technically successful. Twenty-four percent met neither the economical nor technical goal. Another twenty-four percent were successful economically but not technically and nine percent reached their technical goal but overshoot the estimated costs. All in all, 57% of all the ramp-ups from these suppliers were reported as unsuccessful (Meier & Homuth, 2006). The extreme pressure companies face with product launch and to minimizing cost and time of R&D and production ramp-up means that they hurry into the market with volume production (Kontio & Haapasalo, 2005).

A delay of the production ramp-up leads to loss of profits or substantial damage claims by customers. Due to the strong influence of the ramp-up phase on the success of the product, consideration should be made in the early stages of development. (Steffen Elstner, 2014)

These findings stress the issue present with ramp-ups processes which becomes an important and crucial undertaking for companies involved with new product development.
1.3 Scope
The purpose of this thesis is to understand which the common problems in volume production of a contract electronics manufacturer are and how these problems are connected to the project management of ramp-up projects during the product introduction process.

1.4 Research Questions
The developed research questions which are going to be answered throughout this thesis are as follows.

RQ1. What are the most common problems experienced for volume production of products which are connected to the output of the product introduction process?

RQ2. How do the identified factors influence the performance of the product introduction process?

1.5 Delimitations
The thesis researches the current state of volume production at one of the Swedish sites for Orbit One AB in Ronneby as well as their process for NPI projects and product ramp-up. Further on, the thesis focuses only on new product introductions (NPIs) and does not consider product projects issued as engineering change order (ECOs), changes to existing products, or transfer product introductions (TPIs), transfer of existing product in volume production to another site, which also features similar project processes and belonging ramp-up phase. The thesis also not consider further analysis on production problems which are identified as caused by factors external to the NPI project.

1.6 Report Outline
This thesis features six chapters where the first chapter “Introduction” above presents a background to the industry, problem statement to the objective and the research questions of the thesis. Following the first chapter, the chapter “Theoretical Framework” provides a theoretical background for the scope of the thesis. The chapter features a description of common processes found at CEMs, production ramp-ups, NPI projects and project management for NPD. The chapter “Methodology” explains the research design for the thesis, the procedure for data collection, analysis methods as well as how the research methodology is handled in terms of reliability and validity. The results from the data collection is presented in the chapter “Empirical Findings” by explaining the current state of the volume production at the case site and the current process for handling ramp-up of products. The following chapter “Analysis” investigates the effect of the present problems in volume production and what factors from the production ramp-up process that either directly or indirectly affects the current state of production. The thesis report is finalized in the chapter “Conclusion” which summarizes the findings and contribution of the research.
2 THEORETICAL FRAMEWORK

This chapter provides a theoretical background the topic of the thesis scope. It features a detailed explanation of production ramp-ups including the history of origin, the typical ramp-up process, sources of process disturbances and factors influencing the ramp-up projects. The chapter ends with the description of the analytical model and how it is designed in order to analyze the empirical results in the chapter “Analysis”.

2.1 PRODUCTION RAMP-UP

The production ramp-up phase is mentioned as a part of the new product development (NPD) process from the NPD literature and is defined as the last step of this process. One example for this process is given in the following breakdown from Clark and Wheelwright (1992), as seem in figure Figure 1. In this process map of the NPD, the authors name the final step ‘Pilot production/Ramp-Up’. Noteworthy for this representation is that the ramp-up appears before the market introduction.

![Figure 1 - NPD Process adapted from Clark & Wheelwright (1992)](image)

Another NPD process breakdown is proposed by Ulrich and Eppinger (2008), where the NPD process has been split up into six steps and also ends with the phase of production ramp-up (Figure 2).

![Figure 2 - NPD Process adapted from Ulrich & Eppinger (2008)](image)

As highlighted in the examples above, it is the NPD literature which introduces the concept of production ramp-up. However, in the research from the authors mentioned from these examples as well as other authors of NPD literature, they do not study the issues related to production ramp-up in detail. Nonetheless, in the last decade, literature with research studying
production ramp-up has emerged independently with different definitions of the ramp-up phase in the literature.

2.1.1 Definition

The ramp-up phase occurs when a new product is introduced in a factory but also whenever a company sets up a new process or a new plant starts up (Bohn & Terwiesch, 2001; Terwiesch, et al., 2001). Terwiesch, et al., further defines this phase of new product as “[…] the period when a normal production process makes the transition from zero to full-volume production, at or near the levels of cost and quality”. Product ramp-up is thus the phase which directly succeeds process engineering and pilot production. This period carries the characteristic of two conflicting factors: low production capacity, and high demand. The high demand arises because the product is still relatively “fresh” or perhaps yet unseen on the market where the customer is still willing to pay a premium price for the product. However, the production out is low as the production rates and yield has not reached the desired goal. The process-product learning is also poor as many tasks are performed for the very first time. Machine breakdown, slow setups, poor availability or quality of components, and corrective engineering are common features until the learning increases (Terwiesch, et al., 2001). This description of the characteristics of the ramp-up phase is what the researchers in the area of NPD and production ramp-up defines as the ‘ramp-up issue’. The end of production ramp-up is often identified by the achievement of initial product objectives of a ramp-up project such as output volume, cost or yields (Surbier, et al., 2014). Kontio and Haapasalo (2005) define the end of a ramp-up project as when “[…] deliveries are on time, capacity is sufficient, normal efficiency is reached and quality level is acceptable”.

2.1.2 Ramp-Up Process

Regardless of the various definitions from research on ramp-ups the aim of the product introduction process remains the same, which is to develop a production system which facilitates the manufacturing of a product (Winkler, et al., 2007). The product and production system are developed and refined mainly by the development of engineering prototypes, pilot product, pre-series production and volume production ramp-up and possible non-conformities between these production phases are eliminated during the new product introduction process (Fjällström, et al., 2009; Winkler, et al., 2007).

In the illustration below, Figure 3, from Terwiesch, Bohn and Chea (2001) a global view of the life-cycle of a product is given, where the ramp-up phase is also illustrated. With this illustration, some other terms related to new product development and production ramp-up are presented. These terms are defined as follows:

- *Time-to-market* is the development time of a new product.
- *Time-to-volume* is the time to reach full production volume.
- *Time-to-profitability* is the time to reach the initial financial goals.
Although a generally accepted classification of the phases of the ramp-up process has not been established, there are some generally accepted sub-processes which have been identified and scheduled among researchers (Winkler, et al., 2007).

A more detailed process map of the ramp-up phase with these sub-processes is given by Winkler, Heins and Nyhuis (2007) and can be seen in Figure 4.

The rough classification in this process illustration, similar to Terwiesch, Bohn and Chea’s illustration, is the ‘development’, ‘production’ and ‘production ramp-up’. Further in their process illustration, the ramp-up phase has been split into two different steps, the ‘preparation’ phase
(including the start of production with pre-series and pre-production run) and the ‘run-up’ phase (Winkler, et al., 2007).

2.2 CHARACTERISTICS OF NEW PRODUCT INTRODUCTION PROCESS IN LOW-VOLUME MANUFACTURING

The start of the production during the final phases of the product introduction process is often characterized by high levels of production disturbances (Almgren, 2000; Fjällström, et al., 2009). Disturbances such as these can often lead to longer production cycle times (Apilo, 2003; Terwiesch, et al., 2001), lower production output and lower product quality (Terwiesch, et al., 2001). Most of these disturbances has been researched primarily as case studies in the context of high-volume manufacturing industries (Surbier, et al., 2014). The majority of these disturbances are prevented or removed during the product introduction process, which involves different activities to mitigate or eliminate such disturbances (Ruffles, 2000). The product introduction process has been defined differently by different researches, including the model as presented by Winkler et al. (2007). Fjällström et al. (2009) and Johansen (2005) present a more extended model of the product introduction process, as seen in Figure 5, which involves the phases: product and production system development, product test and refinement, pilot production, pre-series production, and production ramp-up. The adapted model of the product introduction process from these researchers can be seen in the figure below.

![Figure 5 - Product introduction process adapted from Fjällström, et al., (2009) and Johansen (2005)](image)

However, the production introduction process as presented above is generically designed to consider the ramp-up process of any manufacturing industry. In a case study by Javadi et al. (2016), the findings showed that the process differs depending on the volume produced by the manufacturing industry. In their study it was shown that the production introduction process in low-volume manufacturing industries is typically limited to the initial three phases (Figure 6).

![Figure 6 - Product introduction process in low-volume manufacturing, adapted from Javadi, et al., (2016)](image)

Since low-volume products are often costly and demand for them is limited and in many cases non-continuous, it becomes infeasible for the company to perform several pilot production and pre-series productions. Another finding from the study showed that the new products are typically modified versions of existing products, which has the direct outcome that the manufacturing industries uses a single flexible production system with slight modifications each process to produce different products in order to avoid high-investment costs in several production systems. Moreover, the study showed that for the low-volume industries the inability to conduct an extensive production ramp-up process lead to that the ramp-up project team
members put more focus into securing the functionality of the product during the product introduction process, resulting in that product requirements critical for the product manufacturability are overlooked and issues with the manufacturability of the product was left to be finalized during the final production. Another observation that was made in the context of the low-volume manufacturing in the case study, was that the use of shared human resources among several product development projects during the product introduction process as well as the on-going production is a characteristic which has implication for the low-volume industry. This resource sharing mainly undermines the involvement of production operators and engineers in the product introduction process, further intensifying the overlooking of product requirements for manufacturability. Further on, the characteristics of a low-volume manufacturing industry were used to identify what the different sources of disturbances during the product introduction process were (Javadi, et al., 2016).

2.2.1 SOURCES OF DISTURBANCES

As potential sources for these disturbances identifies in the product introduction process, Almgren (2000) suggests four main categories; product, production technology, supply of material and personnel. Later studies by other researchers has identified more sources of disturbances in the context for high-volume manufacturing and is summarized by Surbier et al. (2014) into the following seven categories: product, production processes, supply chain and logistics, quality, method and tools, personnel, and cooperation and communication. In the context of a low-volume manufacturing industry, Javadi et al. (2016) identified that the sources of disturbances during the product introduction process could be assigned to the following six categories as seen in Figure 7.

![Sources of disturbances](image)

<table>
<thead>
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<th>Sources of disturbances</th>
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<td>Product</td>
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Figure 7 - Sources of disturbances

In the study by Javadi et al. (2016), it was identified that the product itself was one source of the disturbances experienced during the product introduction process. As the project team was more focused on the product functionality rather than the manufacturability it leads to that the product was handed over to the production with insufficient or incorrect details which can cause frequent disturbances in the early production stages. The short product introduction process also resulted in a lack of opportunities to refine the product and production system due to a limited amount of engineering prototypes which in turn can lead to a poor product maturity and late engineering changes (Javadi, et al., 2016). This goes in accordance with the study by Surbier, et al., (2014), where insufficient product specifications, product changes and lack of product maturity is noted as common sources of disturbances for products.

The production system of a low-volume manufacturer is typically used “as is” with slight modification in order to produce new products. Slight but necessary changes in the production
system are thus typically considered during very late stages of the process or even later during normal production. This problem is intensified with the lack of opportunities to further refine the production system based on the limited number of pilot production runs and the infeasibility of traditional production ramp-up featured in a high-volume manufacturing context (Javadi, et al., 2016). Slow set-ups, unforeseen bottlenecks, poor manufacturability of the product because of inadequate product-process fit are also disturbances resulting from unsecured production systems (Surbier, et al., 2014).

Due to the limited amount of ramp-up production in the product introduction process and the lack of opportunities to refine the product and production system, results in that the communication and cooperation between design, production and the supply chain departments becomes even more important. Javadi et al. (2016) further notes that the complexity and novelty of the product becomes an important factor to consider in the product introduction process. The higher the complexity and novelty of either the product or production system, the earlier the verification of the product manufacturability and conformity between product and production system has to be coordinated in the product introduction process. It becomes important to gather the information and experiences of similar previous projects and ensure that the information is used by those involved in the introduction process of new products during the process (Javadi, et al., 2016). Surbier, et al., (2014) notes that lack of information with logistics and in the new supply chain can lead to problems with materials and components as many suppliers may be unaware that the material is part of a ramp-up resulting in problems with the on-time availability of the components provided by the external suppliers.

The mentioned lack of opportunities for refining the product and production system and adapting them together during the product introduction process can result in quality issues arising at the start of steady production with the final products (Javadi, et al., 2016). Depending on the industrial sector, the quality problems are either handled as rework or an important amount of scrap which leads to further end costs of the product (Surbier, et al., 2014).

As resources are shared among different product introduction projects and on-going production the problems with resource management are intensified. The involvement of production personnel and other production resources in the product introduction process is necessary, however, in many cases it is not easy to plan because of their involvement in the on-going production of other products (Javadi, et al., 2016). Surbier, et al., (2014) also states that many times the methods and tools used for piloting the ramp-up phase are often not specific to ramp-up but are instead the same as those which are used under mature production conditions. These methods are therefore insufficient to take into the account of the characteristics of the ramp-up phase which leads to that the resource planning is rarely accurate.

A critical role in the traditional production ramp-up is the learning and training of the production personnel which is not feasible in the context of a low-volume manufacturing industry with a very short product introduction process. Once again it is therefore important that the novelty and complexity of the project is considered for the learning during the process. Any information and experiences from similar previous projects can help to facilitate the learning during the process (Javadi, et al., 2016). In addition, Surbier, et al., (2014) states that insufficient definition of responsibilities is connected to the disturbances related to personnel.
2.3 FACTORS FOR FACILITATING THE PRODUCT INTRODUCTION PROCESS

These sources of disturbances highlight what factors that are critical in order to ensure a proper output of the product introduction process. Many of the facilitators that are suggested in research in the context of high-volume manufacturing are also applicable for product introduction process in low-volume manufacturing industries but might have an intensified criticality of when and how it should be performed during the process (Javadi, et al., 2016).

As the production system is often considered and used as is it becomes important to identify the requirements and limitations of the production in order to ensure a proper product to process fit. It becomes important that these requirements are considered as early as possible during the process at design level in order to minimize the risk of poor product maturity and late engineering changes in the final phases (Javadi, et al., 2016).

The lack of resources and limited ability of resource management puts more emphasis on how the product introduction process is planned, monitored and controlled in regards of management. Javadi et al. (2016) also suggests that the dedication of the project managers and how they coordinate the whole process is an important facilitator which can make up for the resources that are tied between new product development projects and on-going production.

In the study by Javadi et al. (2016), it was concluded that the high amount of disturbances related to missing or incorrect information suggests design details are neglected, under-prioritized or not communicated in the production. Lack of resources and opportunities for product and production system refinement were also identified as the main causes for the challenge of communication and information sharing.

The characteristic of low amount of prototypes and production runs in low-volume manufacturing also resulted in a more focused view on securing functionality over manufacturability in pilot production. The lack of opportunities to test and refine the product and production system results in that it becomes even more important how the production is involved in the product introduction process and how the pilot production should be performed in order to secure product manufacturability, costs and quality of the end product (Javadi, et al., 2016).

2.3.1 PRODUCT-PRODUCTION REQUIREMENTS

In a study on new product introduction processes in contract manufacturing, Apilo (2003) works on how the new product introduction time can be reduced for electronics manufacturers. In this study it is discussed that the drivers for successful ramp-up projects are given as: a formal and well-understood stage/gate project model, extensive review meetings at every gate, the implication of presence of every stakeholder, planning, and lastly feedback/lessons learnt for future projects (Apilo, 2003).

New Product Introduction (NPI) projects in contract electronics manufacturing (CEM) are conducted whenever a new product from an original equipment manufacturer (OEM) is ordered for production at the CEM. Apilo (2003) defines a NPI project as “[…] the co-operative process of combining and integrating the needed organizations, functions, and activities cost-efficiently in order to bring the new product from R&D to full-scale manufacturing in a supply chain environment”. The illustration from Apilo (2003) illustrates the definition of ramp-up, production
ramp-up and NPI with cost curves for both OEM and CEM during a product development and product launch phase.

A NPI can be featured for an already existing product program of an OEM or it can be conducted whenever a new customer is contracted to the CEM. For many contract manufacturers and suppliers this is another difficulty to handle, even though they usually operate in continuous process mode, because of NPIs in a product program or production ramp-up they also have to operate in project mode (Kontio & Haapasalo, 2005).

The key difference for ramp-up projects in a contract manufacturing environment is that the activities featured in the development period which precedes the ramp-up phase for a new product is owned by the OEM. Although, for many ramp-up projects some design activities are shared between OEM and CEM where DFX such as design for manufacturing (DFM) and design for assembly (DFA) is conducted at both companies in order to adapt the product design for the requirements of the manufacturing facility it is introduced in. Similarly, CEMs needs early information about production methods, components and time schedules before the ramp-up project is started.

An example of the NPI process from Apilo (2003) shows the common activities featured in the process and how they are shared between the OEM and CEM.
The first part of the process focuses on setting the specifications and requirements for the product with regard to the CEM’s manufacturing capabilities. Once the preliminary product design is set, material sourcing and production planning is performed in detail in order to set the project planning and cost of the ramp-up. Non-recurring engineering (NRE) such as, tooling, fixtures, and programming are also performed up until the prototype run. After the prototype run, a report of manufacturability is sent back to the OEM for possible product tuning. If the prototype run is performed in a separate prototype line, a null-series can be performed in a close to possible mass production environment to further validate the product’s manufacturability. The ramp-up project is ended with feedback to the OEM for possible fine tuning to further improve the conditions for mass production. Gates are set for each phase in the NPI process, and for each production run a target yield is used as a upper-boundary criterion to determine pass or fail for the gates related to the production runs (Apilo, 2003).

An important part of the NPI process for a contract manufacturer as explained by Apilo (2003) is the involvement and cooperation between the OEM product design team and the CEM engineering and production in order to ensure a proper product to process fit. As concluded by Ruffles (2000), an important factor to improve the new product introduction process in manufacturing companies, is to involve production and knowledge of the production requirements early in the process. Concurrent engineering between customer and supplier is necessary throughout the process with involvement of all disciplines associated with design, manufacture and support of the product.

Adding to this, Adler (1995) concludes that design reviews performed throughout the process is necessary in order to facilitate the product introduction process. In his study, Adler (1995) also suggests that an improved assurance of product manufacturability can be obtained by limiting material usage to components with known manufacturability and developing manufacturability databases with the usage of information and experience from previous similar projects.
2.3.2 Management of Product Introduction Projects

By using the general goals of a NPD project, Winkler, et al., (2007) defined the following five targets for how a ramp-up project should be managed:

1. Strengthening of resources for high productivity
2. Product realization
3. Strengthening of resources for high quality
4. Grounds for low costs
5. Short intervals between milestones

The first target regards upgrading of processes or training of workforce in order to achieve high productivity. The second target puts emphasis on that deviations from the planned ramp-up curved must be kept to a minimum in order to avoid endangering of sales targets. Not only does this require production according to the planned volume and its availability at the production output, it also means producing to the planned quality, which is enabled by the third target. The third target highlights that in order to reach the required quality of the product the corresponding production processes must reach a minimum level of quality. This refers to the level of performance of machinery, raw material, and workforce. The fourth target refers to that the achieved revenue of the final product should be maximized. This in turn requires that the number of ramp-up operations are minimized, the operations themselves must be designed to be cost-effective. The final target stresses the importance of keeping to the ramp-up time-table. A well-managed and time-efficient ramp-up project will maximize the profitable phase of a products life-cycle (Winkler, et al., 2007).

Ramp-up production systems are often characterized by a number of significant problems such as delays and product quality issues. It is therefore the task of the manager of a ramp-up project to eliminate or minimize any disruption. The tools and method used for managing a ramp-up project are similar to those of traditional project management. For example, Gantt-charts can be used for planning deadlines and milestones and risk assessment with tools such as FMEA or DFX-analyses can be performed to foresee possible disruption outcomes (Winkler, et al., 2007).

In a study by Bauer, et al., (2014), failure management was also discussed as a factor for identifying unforeseeable events and disruptions proactively in the management of ramp-up projects. The failures may be due to technical or organizational reasons, but in order to rapidly achieve proper product maturity the main objective for ramp-up management is to eliminate all failures as quickly and effectively as possible. In order to ensure shorter reaction times on failures, the manager has to be aware of the organizational interface between project team members, process transparency and the clarity of roles and responsibilities.

Elstner and Krause (2014) also mentions in their study how risk management with consideration to the product's complexity and novelty can be used in management of ramp-up projects in order to improve the performance during the product introduction process. Early identification of risk drivers related to design, material, and production is used in order to effectively implement management strategies for performing proactive and reactive activities in order to minimize or eliminate possible ramp-up risks.
2.3.3 Supply Chain Communication and Information

Because the product introduction process requires the establishment of a temporary organization with cross-departmental project work the communication interface between the different project members becomes an important factor during the product introduction process. Surbier, et al., (2009) explains in their study how the flow of information and cross-departmental interface is an important factor to consider in order to ensure efficient communication and cooperation through sufficient communication channels during the process. As information regarding the product and production system the interface often stems from the Engineering department is becomes important to consider the maturity of the information at the start of a ramp-up project in order to prevent inadequate product maturity and that late engineering changes occur which might affect the correctness of the information of the product and production system. The Purchasing plays a key role in setting up the new supply-chain and with establishment of material data information on the new product and purchase new materials and components for production. The production is often the receiver of the final information from the departments involved in the process, however, they are also an important supplier of feedback on the information given in order to adjust and correct the information during the process (Surbier, et al., 2009).

Fjällström, et al., (2009) summarized the most critical types and sources of information for for problem events which occur during a production ramp-up into six different categories. The categories can be seen in the Table 1 together with the most common type of information which regards the information source.

Table 1 - Sources of information

<table>
<thead>
<tr>
<th>Suppliers/Supply</th>
<th>Availability and quality of materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product/Quality</td>
<td>Output quality, Adjustments of products</td>
</tr>
<tr>
<td>Equipment/Technique</td>
<td>Machine handling</td>
</tr>
<tr>
<td>Process</td>
<td>Disturbances, Additional work tasks</td>
</tr>
<tr>
<td>Personnel/Education</td>
<td>Knowledge level of operators, Task environment</td>
</tr>
<tr>
<td>Organization</td>
<td>Resource capacity, Urgent problems</td>
</tr>
</tbody>
</table>

Fjällström, et al., (2009) also concludes in their study that although the information could be sorted into different categories based on the information of the identified problem events, parts of the information often concerned one or more of the other categories. As for an example, when handling problem events related to the product, the information were not solely product/quality information but also information about the machines and process were required as well. Based on this, Fjällström, et al., (2009) concludes that there is a need of a holistic perspective when handling information regarding problem events during the product introduction process. Information strategies must be implemented in such a way that meetings between involved personnel are enabled and the content of the information should be structured so that it contains information regarding problem and domain sources which partly confirms and partly updates or renews the progress of the ramp-up situation (Fjällström, et al., 2009).
2.3.4 Pilot Production and Final Process Verification

A manufacturing industry’s ability to rapidly ramp-up the production of a new product is heavily dependent on the company’s capability and responsiveness to manage sources of disruptions identified during the product introduction process.

The results of a study by Almgren (2000) concluded how identified disturbances during the pilot production of a ramp-up could affect the production performance of a new product. The identified disturbances resulted in loss of production capacity or increased production load due to problems such as; machine downtime, quality losses, reduced manufacturing speed, operator performance, and material shortages. The study proposes that in order to succeed with rapid and efficient ramp-up of new products the production organization should focus on identifying sources of disturbances as early as possible during the pilot production in order to gain control of these before the final verification of the process. In order to improve the final verification of the production performance during a ramp-up, the production system should therefore be tested as close to normal production as possible with focused organizational support from the product introduction project team. Putting load on the production system during the pilot production enables the involved functions in the product introduction process to more effectively identify sources of disturbances and capacity limitations which might affect the final performance. However, to properly enable improved learning, problem-solving and disturbance control during production of a new product, the pilot production needs to be supported by the production organization which is engaged in the final verification of a product and production system (Almgren, 2000).

A study from Li, et al., (2014) further extends on the subject of verification of the production performance in the context of ramp-up in a supplier network. Using a systematic ramp-up process and framework for early identification and rectification of potential disturbances during the ramp-up process resulted in less rework and scrapping during the pilot production. The systematic ramp-up process also uses a fallback loop whenever a disturbance is identified, leading to that the disturbance has to be rectified before the process can continue. Based on the results of the study also suggests that the usage of a shared ramp-up process within the supplier network improves the predictability of production yields and thus strengthens the accuracy of production planning and delivery performance (Li, et al., 2014).

The success of new products is usually measured in terms of their financial results and the companies must therefore analyze the financial profit for each new product. The hardest part of the cost estimation of a new product is to assess the future costs at the planning stage. There are two methods which may be used at this stage to assess the future cost of a new product, the intuitive and analogical methods. The intuitive technique assesses the cost based on expert knowledge and extensive experience which makes the laborious and expensive. The analogical requires historical data and bases the cost estimation on the financial information from similar previously executed projects. The most accurate cost analysis results are obtained at the stage planning of the manufacturing process. As detailed information and description of the manufacturing is known enables the use of better analogical methods of estimation as operational tasks and resources assigned to the process are known. The estimated costs is also the basis of assessment of the correctness of the process and any deviations must therefore be corrected immediately by decisions taken during the ramp-up process. Cost management therefore plays an important role and monitoring and control of costs must be
carried out during the product introduction process in order to verify the end costs tied to the product and the production system (Chwastyk & Kolosowski, 2014).

### 2.4 Analytical Model

In Figure 10 on the next page, the analytical model of the thesis is presented. The model will be used as a basis for how the empirical results will be analyzed. The identified problems in volume production at the company resulting from the data collection will initially be analyzed in comparison to the sources of disturbances as presented by Javadi, et al., (2016) in order to answer the first research question of the thesis. The study from Surbier, et al., (2014) will also be used to complement the analysis in the initial phase. As the problems in the volume production can be caused by either external or internal sources of disturbances from the product introduction process, the problems have to be analyzed basis of the characteristics of the production to determine which problems are caused by NPI project internal sources of disturbances.

After the project internal sources of disturbances has been identified for the volume production problems the second research question will be analyzed through the theories on which factors which facilitates the product introduction process as mentioned in the study by Javadi, et al., (2016). The main areas of these factors has been categorized as follows; Product-Production Requirements, Management of Product Introduction Projects, Supply Chain Communication and Information, and Pilot Production and Final Process Verification.

To understand how the involved NPI project functions consider the production’s requirements and limitations and how it affects the project during the introduction of a new product, the project factors identified from the data collection will be analyzed on the basis of the theories from Adler (1995), Apilo (2003), and Ruffles (2000).

The high possibility of constrained capacity of resources and high process uncertainty during the product introduction process requires dedication in the aspects of planning, monitoring and control of project management. In order to analyze the level of management dedication and how the NPI projects are controlled Bauer, et al., (2014), Elstner & Krause (2014), and Winkler, et al., (2007), will be used.

As the product introduction process requires high involvement of cross-functional teams, it becomes important to understand the requirements of the project’s informational interface and what level of communication is needed between involved functions. The studies from Fjällström, et al., (2009) and Surbier, et al., (2009) will be used in order to analyze what the NPI projects require in the aspects of informational flow and supply-chain cooperation.

Finally, the pilot production and the final verification of the product introduction process will be analyzed with Almgren (2000), Chwastyk & Kolosowski (2014), and Li, et al., (2014). The aim is to identify how the NPI projects are verified in terms of manufacturability, quality and costs of the final product and production system.
Figure 10 - Analytical model
3 Methodology

In this chapter the methodology applied to the research is presented. It describes a brief introduction to the subject of research methodology and the connection to the chosen research design of the thesis. It also explains the chosen methods and use of data collection and analysis. To assure the quality of the research in the report, this chapter will elaborate how the report will be evaluated according to reliability, validity of the result and implications of bias in the research.

3.1 Thesis Research Design

The main approach for the research behind this thesis is based on a combination of inductive and interpretive research approach with gathering of qualitative data from a single case study.

In-line with the interpretive approach the main resource of data available for the research was through the experiences and knowledge of the individuals involved with the production ramp-up process at the case company. The human experiences are mediated through different set of values, terminology, and expressions related to field experience. The means of this approach is to create an understanding and interpretation of the knowledge and subjective experience adhered to the projects and processes at the company. Although the research itself is somewhat explorative in the ramp-up relationship for supply chains, additional theory and character of knowledge are already existent for ramp-up processes in the electronic industry.

The interpretive approach helped to create preliminary data for explaining and understanding the reality of ramp-up processes and management at a contract manufacturer as well as defining important variables and their relationships to add to the sparse theory on ramp-up processes for contract manufacturing.

The inductive reasoning is important as a base for coupling the dynamic setting at the case company to previous research and with the qualitative data to build new theory about this research phenomenon. As the inductive approach is quite resource demanding and due to the multiple interactions in the process the approach was realized through a single case study at one of the company sites.

The case study approach of this thesis followed the strategy for case research suggested by Eisenhardt (1989). Her research with a case approach suggests a highly iterative case research process with tight linkages to gathered data with the result of novel theory with empirical validity. The framework, or roadmap, from her research is summarized in Table 2.
Table 2 - Process of Building Theory from Case Study Research, K. Eisenhardt (1989)

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Getting Started</strong></td>
<td>Definition of research question</td>
<td>Focuses efforts</td>
</tr>
<tr>
<td></td>
<td><em>Possibly a priori constructs</em></td>
<td>Provides better grounding of construct measures</td>
</tr>
<tr>
<td></td>
<td>Neither theory nor hypotheses</td>
<td>Retains theoretical flexibility</td>
</tr>
<tr>
<td><strong>Selecting Cases</strong></td>
<td>Specified population</td>
<td>Constrains extraneous variation and sharpens external validity</td>
</tr>
<tr>
<td></td>
<td>Theoretical, not random, sampling</td>
<td>Focuses efforts on theoretically useful cases – i.e. those that replicate or extend theory by filling conceptual categories</td>
</tr>
<tr>
<td><strong>Crafting Instruments and Protocols</strong></td>
<td>Multiple data collection methods</td>
<td>Strengthens grounding of theory by triangulation of evidence</td>
</tr>
<tr>
<td></td>
<td>Qualitative and quantitative data combined</td>
<td>Synergistic view of evidence</td>
</tr>
<tr>
<td></td>
<td>Multiple investigators</td>
<td>Fosters divergent perspectives and strengthens grounding</td>
</tr>
<tr>
<td><strong>Entering the Field</strong></td>
<td>Overlap data collection and analysis, including field notes</td>
<td>Speeds analyses and reveals helpful adjustments to data collection</td>
</tr>
<tr>
<td></td>
<td>Flexible and opportunistic data collection methods</td>
<td>Allows investigators to take advantage of emergent themes and unique case features</td>
</tr>
<tr>
<td><strong>Analyzing Data</strong></td>
<td>Within-case analysis</td>
<td>Gains familiarity with data and preliminary theory generation</td>
</tr>
<tr>
<td></td>
<td>Cross-case pattern search using divergent techniques</td>
<td>Forces investigators to look beyond initial impressions and see evidence through multiple lenses</td>
</tr>
<tr>
<td><strong>Shaping Hypotheses</strong></td>
<td>Iterative tabulation of evidence for each construct</td>
<td>Sharpens construct definition, validity, and measurability</td>
</tr>
<tr>
<td></td>
<td>Replication, not sampling, logic across cases</td>
<td>Confirms, extends, and sharpens theory</td>
</tr>
<tr>
<td></td>
<td><strong>Search evidence for “why” behind relationships</strong></td>
<td>Builds internal validity</td>
</tr>
<tr>
<td><strong>Enfolding Literature</strong></td>
<td>Comparison with conflicting literature</td>
<td>Builds internal validity, raises theoretical level, and sharpens construct definition</td>
</tr>
<tr>
<td></td>
<td><strong>Comparison literature with similar</strong></td>
<td>Sharpens generalizability, improves construct definition, and raises theoretical level</td>
</tr>
<tr>
<td><strong>Reaching Closure</strong></td>
<td>Theoretical saturation when possible</td>
<td>Ends process when marginal improvement becomes small</td>
</tr>
</tbody>
</table>

In order to answer the research questions, and in adherence with Eisenhardt’s framework, the research process for this thesis followed the model presented in Figure 11.

![Figure 11 - Research process](image-url)
The research questions involve investigation of two separate but connected processes, NPI and Volume Production. The research process was therefore divided and conducted in two separate rounds of process investigations with planning, data collection, analysis and theory building. As the two processes have different stakeholders, the process started with theoretical sampling which means that samples were selected upon in favor for what they could contribute with to the theory. Appropriate theoretical samples were chosen in order to identify which sources of information and knowledge are critical to the process, limit variation of the findings, and help to define the limits for generalizing the findings as suggested by Eisenhardt (1989).

The first round of the research process aimed to investigate the current state of the volume production at the case company. It involved planning of data collection relevant for the volume production, data gathering, analysis and theory building for the current state. The reason for targeting the volume production first hand was to build an understanding of current status of the production, which parties are involved in the process and who are affected by its current performance.

The second round investigated the process for product ramp-ups and NPIs. Additional stakeholders, variables and questions identified from the first round was added to the research sampling and data collection methods. Through this research process the aim was to map the two processes, identify the effects of the output from the ramp-up projects on volume production and the project factors behind these effects.

3.2 DATA COLLECTION METHOD

A typical method for theory building case research among researchers is to combine multiple data collection methods to create triangulation with the findings to provide strengthened substantiation of constructs and higher internal validity. Moreover, by effectively combining qualitative and quantitative data collection methods can create a highly synergistic data collection method with several benefits. Quantitative evidence can indicate relationships which may not be emergent to the researcher in the qualitative evidence. It can also keep the researcher from exploring false impressions from the qualitative findings which may not be of benefit. Also, quantitative data can strengthen findings when they corroborate with qualitative evidence. Qualitative data are especially useful to understand the rationale or theory behind relationships revealed in quantitative data and may thus suggest theory which can be directly supported with quantitative evidence (Eisenhardt, 1989).

The same method of triangulation of data was used during the research process for this thesis and the triangulation of collected data was based on the following data sources:

- Interviews,
- Observations and field notes,
- Secondary data.

Qualitative data findings were realized through multiple sets of semi-structured interviews as well as informal interviews. The informal interviews were used to form initial knowledge about the processes and to identify important themes and topics for the semi-structured interviews. The qualitative data collection was supported with passive observations of NPI projects at the case company and running field notes to compare data from interviews with research subjects to how they would act in a dynamic setting. Finally, the interviews and observations were
combined with qualitative and quantitative data from secondary data available from the case company.

3.2.1 SAMPLING

The sample selection for the interviews and observations in the case study were performed through theoretic sampling as described by Eisenhardt (1989) of research subjects with one of the following relationships to the processes: Influencing the process, involved in the process, or affected by the process. The sampling plan were further enhanced with a number of tests as suggested by Miles & Huberman (1994):

- Is the sample relevant to the conceptual frame and research questions?
- Will the phenomena to be studied appear? Can they appear?
- Is the sample on that enhances generalizability?
- It is feasible?
- Is it ethical in terms of informed consent, potential benefits and risks and relationships with informants?

To answer these questions and to verify the correctness of chosen samples the strategy for theoretical sampling is carried with the help of the head of project and process management at the case company who acts as a principle informant for this thesis as explained by Voss, et al., (2002).

The sampling of the interviewees for the data collection was performed with the help of the company supervisor in order to gather data from persons who have both long-term experience of volume production and varied experience from participation in many NPI projects. The interviewees represent one function of the main production departments as these are the departments that has a direct effect on the operation of the production and who also has a participating role in the project team of a NPI project.

The sampling of the interviewees for the data collection on factors influencing the NPI projects was performed with the same method as in the first round of interviews. As in the first round of interviews, the interviewees represent one function of the main production departments and account management and the selected persons for the interviews were the same with the exception of one product engineer.

3.2.2 INTERVIEWS

For a theory building case study with an explorative research purpose, in-depth (unstructured) and semi-structured can be more favorable over structured interviews as these are often referred to as qualitative research interviews because of their ability to produce qualitative findings (Saunders, et al., 2007).

The majority of the field data for the thesis was collected through interviews with a combination semi-structured and unstructured interviews in order to gain as deep insights of the field as possible. The initial round of interviews is conducted in an informal group setting with the account managers at the company who act as responsible for both the introduction of new products and further production of the product in volume production. The unstructured interviews are used in order to understand the current state and methodology of the processes and their relationships with other involved departments and are recorded with notes taken by the interviewer. This knowledge was then used as a basis for setting up and to plan the semi-
structured interviews with all involved departments, represented by one individual. This individual may have a varied previous experience from the process to add to the variation of employee work experience as long as their knowledge of working with both processes previously can be verified by another instance.

The semi-structured interviews are conducted one-on-one with the interviewee with predetermined questions which are constructed from emergent themes and questions from previous unstructured interviews and observations. All semi-structured interviews are recorded with consent of the interviewee and later transcribed by the interviewer. The transcription is then reviewed by the interviewee in order to verify the interview's content before any analysis.

In order to iterate data collection and analysis the interviews were separated into two rounds with different focus of topic. The first round of interviews featured questions which focused on what the department’s responsibility was, the work process in volume production for the department and which reoccurring problems they usually faced in their work. The roles and number of people featured in the first round of interviews were:

<table>
<thead>
<tr>
<th>Role</th>
<th>No of people interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamleader</td>
<td>2</td>
</tr>
<tr>
<td>Production Manager</td>
<td>1</td>
</tr>
<tr>
<td>Planner</td>
<td>1</td>
</tr>
<tr>
<td>Purchaser</td>
<td>2</td>
</tr>
<tr>
<td>Production Engineer</td>
<td>3</td>
</tr>
<tr>
<td>Quality Engineer</td>
<td>2</td>
</tr>
<tr>
<td>Account Manager</td>
<td>1</td>
</tr>
</tbody>
</table>

The second round of interviews featured questions which focused on the departments’ degree of involvement, project responsibilities, and possible shortcomings in the execution of NPI projects. The roles and number of people featured in the second round of interviews were:

<table>
<thead>
<tr>
<th>Role</th>
<th>No of people interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamleader</td>
<td>1</td>
</tr>
<tr>
<td>Planner</td>
<td>1</td>
</tr>
<tr>
<td>Purchaser</td>
<td>1</td>
</tr>
<tr>
<td>Production Engineer</td>
<td>2</td>
</tr>
<tr>
<td>Quality Engineer</td>
<td>1</td>
</tr>
<tr>
<td>Account Manager</td>
<td>2</td>
</tr>
</tbody>
</table>

3.2.3 OBSERVATIONS
To increase the validity and reliability of data the understanding of tacit knowledge in the management field must also be considered. The non-direct and unspoken knowledge, which is transferred between individuals working in the management departments, can be captured through observations. Thus, increasing probability of finding convergence and clarification of the relationship and variables discovered throughout the research process (Voss, et al., 2002). Observations as a spectator in the role 'participant as observer' as mentioned by Voss, et al.,
(2002) at meetings has another advantage alongside insights gained through direct observation.

In the research process in this thesis, observations at project management meetings at the case company has been conducted alongside the former data collections methods in order to refine questions further for forthcoming interviews and to further understand how the account managers operate at the case company. Directed and in-depth observations of certain process steps has also been conducted in the production order to gain a better overview and understanding of the certain problem areas and bottlenecks which affects the management of the production.

3.2.4 Secondary Data
Secondary data or archived data at the case company include both quantitative and qualitative data with the main advantage to find plentiful of objective evidence without huge efforts of resources. These documents provide findings of managers’ reasons for decisions or readily data to generate statistical measures from. Secondary data can be used to further triangulate primary data collected by the researcher and to place the findings in a more general context (Voss, et al., 2002).

For this thesis, the main sources of secondary data will be obtained through the following information:

- Historical project data
- Process procedures & policies
- Process guidelines

However, as secondary data has been collected for a specific purpose that differs from the thesis research objective they might not be appropriate in order to answer the research questions. In order to control the secondary data’s relevance for the research the content of the data has to be reviewed for information which enables the researchers to answer the thesis research question(s) or meet the research objectives. The secondary data also need to hold formal validity and credibility in the case company.

The company provided historical data on NPI projects which was used in order to compare similarities and differences between project teams, products and scope of the project. The historical data on NPI projects were also used in order to validate the results from the interviews as historical problems from the projects were documented as well.

Process procedures, guidelines and policies were studied in order to understand how the case company had standardized the processes and how the processes were supposed to be carried out in theory. These documents were used in order to compare the results from the interviews with how the employees were supposed to operate in the processes.

3.2.5 Bias
The mentioned data collections presented in this research methodology presents different forms of bias. Whether if it is bias in interviews through the interaction between interviewer and interviewee, ambiguous interpretations of a situation from the observer, or biased views and preconceptions in the recordings of secondary data, the researcher has to be aware of the implications it might lead to for the results of the analysis (Voss, et al., 2002).
In order to limit the influence of bias in the research process and to minimize false assumptions and incoherent logic leaps in the analysis, the following measures has been taken in order to improve the control over the data collection process.

As mentioned earlier, the described "record-transcribe-review"-routine for interviews ascertain that any data from the recordings are valid from the point of the interviewee. False assumptions made from erroneous interview recording are thus kept to a minimum and the analysis is left to the axiomatic judgment of the researcher. Predetermined themes and questions prior to any interview are also verified and validated with both primary company informant and external researchers involved with the process of the research.

Secondary data, as earlier mentioned, can involve many implications to validity and reliability. The primary informant again acts as a verifier of any secondary data retrieved from the case company and has been used during the research of the thesis to validate any secondary data used in the thesis. Many formal data records and written documents also include notes of internal approval from a process owner which acts as further support for the data’s validity.

Running field notes has also been taken throughout the research process not only to capture the researcher’s thoughts and points of interest to pursue, but also to differentiate objective information from any subjective interpretation and initial analysis from the researcher.

### 3.2.6 Literature Study

Although usage of existing theory in a case research should be kept to a minimum (Eisenhardt, 1989), a preliminary literature study with critical review can be suitable to provide a foundation for the research. The main purpose is to develop a good understanding and insight into relevant previous research and trends that have emerged in the research area. In conjunction with the inductive research approach, literature studies are used to research relevant theory or other case studies which subsequently will be tested to the result and developed theory (Saunders, et al., 2007).

The vast majority of literature acquired in this thesis was gathered through online databases. The main source was the online database of the Linköping University’s library for the majority of literature. In addition, Google Scholar was used in order to locate even more material of interest. Reports and articles in the research which are published in a peer-reviewed journal are used in favor of other material. Various keyword and combination of keywords such as ramp-up, industrialization, and production management as well as other synonyms for these were used to find a broad range of material which might be of use. Cited articles in the found literature which had an exceptional fit to the purpose of the research were used in order to add even more literature to the research.

### 3.2.7 Closure

An important question for the research process is when to stop iterating between theory and data. The key idea to this question according to Eisenhardt (1989) is theoretical saturation, which explains that the iteration process should be ended when the incremental improvement to the theory is minimal.

For this thesis, theoretical saturation has been used as a definition for when the research process should end.
3.3 Method for Data Analysis

The data collection and analysis in the defined research process are two overlapping processes. Not only does this process give the researcher a head start in analysis, more importantly it lets the researcher take advantage of flexible data collection effectively creating adjustments to the data collection protocols and instruments along the progress of the research. Although early analysis with identification or research questions and possible constructs can prove helpful, it is important to note that any initial analysis has to remain tentative as no construct is guaranteed a place in the resultant theory of the research. It is also important to note that theory building research should be begun with as little theory under consideration as possible and therefore leaves out any thoughts about specific relationships between variables and theories until the data collection is finished (Eisenhardt, 1989).

For the analysis of this thesis, an analytical model has been constructed in order to analyze which problems found in the volume production of the company that are linked to certain project factors. Throughout the data collection of the thesis, this possibility of linking certain identified problems to project factors has been considered and explored iteratively in order go deeper into the actual root cause of the production problems. However, premature confirmation of linkages has been kept out by from the analysis by letting the final analysis with the analytical model when the data collection has reached closure.

3.3.1 Within-Case Analysis

The overall idea with within-case analysis is for the researcher to become intimately familiar with the dynamic setting of the case study. This step of the analysis allows the researcher to identify unique patterns and linkages between in-case variables before the research is pushed to generalize across cases (Eisenhardt, 1989).

The data collection of problems with volume production, project challenges and possible factors are sorted and categorized, and presented on each end of the analytical model. The process of the analytical model starts with the identified problems which through the steps of the model should be linked to possible project factors and other data which confirms the possible outcome from the project output. In this first step of the analysis, all collected data will be considered for the company as a whole. As one NPI project case with only a few difficulties still can generate critical problems in the production with implications for the company as a whole, these will be considered as valid as NPI project cases which generate multiple problems in production. However, the full analysis will only be considered for any data which are found to be link to project internal factors.

3.3.2 Cross-Case Analysis

Building on the individual case patters of data the next step is to seek convergence or divergence of patterns across cases. The reason behind this is because humans are prone to jump to conclusions based on a limited amount of data. The danger with this phenomenon is that researcher might reach premature conclusions, ignore statistical properties or even inadvertently drop disconfirming evidence. Thus, the researcher is inclined to make false assumptions as a result. The cross-case analysis counteracts these tendencies by looking in the data many divergent ways (Eisenhardt, 1989). The strategy used for this analysis is to perform a construction of an array of the summarized data. The array is categorized by identified variables and relationships to compare the case studies in order to find similarities and differences, even subtle ones (Voss, et al., 2002).
Building on the previous strategy from the within-case analysis. The analyzed production problems linked to their corresponding project factors from on NPI case were in the next step analyzed through comparison with their project context and setting with other NPI projects. As different projects are tied to different customers, project teams and contextual settings, this cross-case comparison helped to further understand how these problems arise and the root cause behind them. This next step in the case analysis ensured further validity and reliability of the collected data. The generalizability of the results was heightened through cross-case comparison with other case research within the same field of research, as seen from the cited literature featured in the analytical model.

3.3.3 Validity, Reliability and Generalizability

Reliability testing aims to minimize errors and bias throughout the research process. The importance of a good case reliability is to ensure the extent of which the case study’s operations can repeated by another researcher and provide the same result (Voss, et al., 2002).

Generalizability in case research addresses how well the findings from the case study are supported with existing literature as well as future research in the field of area. Cross-case analyses and comparisons with literature for similarities and differences, heightens the level of which the research can be generalized (Voss, et al., 2002).

The use of data triangulation, a highly structured analysis methodology, protocols and field note documentation throughout the research process are means in order to increase validity, reliability and the probability of replication of the case study. As the research is limited to a single case site because of the stated demand of resources these methods were used to secure both internal validity of the case conclusions as well as the generalizability of the analysis with the cross-case analysis.
4 Empirical Findings

This chapter will present the case company and describe how the organizational structure and department responsibilities are structured at the company. It will also explain how product are manufactured at the company. The chapter will then present the results from the data collection with which problems has been identified in the volume production of products. A brief explanation on how the NPI projects are performed will then be presented, followed by the identified factors which influences the performance of the NPI projects at the company. The chapter ends with findings from additional data sources together with a summary of all the findings from the data collection.

4.1 Introduction to Case Company

The case company for this thesis, Orbit One AB, has been experiencing fluctuating levels of performance connected to volume, cost and quality in volume production which is thought to be the result of their management of product ramp-up projects for New Product Introductions (NPI). The case site was recently under ownership of the international competing CEM company Flex, but were acquired by Orbit One AB in the fall of 2015. As of this acquisition, the company sees the opportunity to investigate the problems experienced in volume production and how they are linked to the product ramp-up projects in order to improve the project management of NPI projects.

Orbit One AB is a contract electronic manufacturer of printed circuit board assembling and box building of electronic products. They also offer integrated logistics solutions for their customers, minimizing intermediate logistics handling and include shipping directly to the end-customer. Orbit One AB is an international enterprise with their production facilities situated in Europe with 650 employees distributed among their sites located in Sweden, Poland and Russia with its headquarter located in Ronneby, Sweden. The business vision of the company states that the company should be the “[…] preferred partner of choice for customers who require reliable & flexible assembly and integration services” and their business values are dedicated to continuous improvements, achieving top performance, long-term partner commitment and responsiveness to customer needs. These values are reflected in their production and management system which works in accordance to KPIs and has adopted Lean philosophy and solutions to continuously improve their performance. The company is certified for ISO9001 and ISO14001 which means that the company has an implemented management system for both quality and environmental aspects of manufacturing. Their Swedish sites are also certified for ISO13485 which is a prerequisite in order to produce products for the medical industry.

Their main production facility, Orbit One West, is located with the company headquarter in Ronneby, Sweden, which is integrated with the new production site recently acquired from Flex in 2015. The production site involves many manufacturing services from fully automated manufacturing of PCBs, box-build assembly, in-house testing, PCB conformal coating & potting as well as end packaging and the production is designed for a single production flow from bare PCBs to final assembly of product. They also offer services for NPI and after-market from early design review of products with design for manufacturing (DFM) to after-market repairs and handling of technical documentation during its product lifecycle.
At this site, 16 customers are contracted to their production and each year several NPI projects are conducted for each customer. During the last four years, the site has in average completed 127 NPI projects per year and in 2015, 117 NPIs were completed with an average completion time of 8-10 weeks. These projects present new products to their production to either phase out existing or outdated products or add to the product portfolio for each customer. These projects are managed by the company’s NPI process model and belonging support systems which controls necessary project activities, department responsibility and follow-up of the pilot production to compile a report of the product’s manufacturability and a list of required actions to secure the product’s quality and manufacturability. When the customer has reviewed and verified the design of the prototype or pre-series of a product the project is often followed by an order for volume production of the product. Following the customer order, the production of the product is ramped up and manufactured in volumes according to the order, which can be ten times the prototype volume or greater. Due to the larger batch sizes this process step often presents issues not identified earlier in the NPI process. Issues such as product quality not reaching set yield, components not delivered within lead time and unverified process problems are known to be a common experience for products in their volume production which results in longer lead times to the customer and added product cost. As the cost for a product are quoted during the NPI process, for a contract manufacturer, while the problems can surface later on in volume production, these problems could potentially result in producing at a loss and in a worst case scenario prolonged issues with production could lead to a loss of contract with the customer.

4.2 ORGANIZATIONAL STRUCTURE AND DEPARTMENT RESPONSIBILITIES

The organizational structure of the company can be seen in the figure below. The Chief Operating Officer (COO) is the managing person of the operations of the production facility and the functions involved with planning, managing and producing the products. Directly under the COO is the support functions Economy, HR and IS/IT which handles more administrative work. The Supply Chain function is responsible for strategic work and planning of the company regarding purchasing partners, logistic solutions and cooperation with the other production facilities. The Account Management department has a dual role in the organization and handles both product and project management. They are also responsible for handling contract management with customers, quoting of new product offerings and forecasting for orders on products from the customer. Although they are seen as a supportive function in the organizational structure, they are closely involved with the other business functions and the production of the company. The Account Management department and their work with projects and volume production will be explained further in the end of the chapter.
The other departments seen in the bottom of the organizational structure, highlighted in red, are more directly involved with the production of the company. These departments will be mentioned as the main production departments and their work and responsibilities will be explained further throughout the chapter.

**Production**

The Production department currently has two managers responsible for the management of human and machine resources in the production which involves personnel competence development as well as machine and production line management and improvements. One manager is responsible for every process related to Surface-Mounted Technology (SMT) while the other manager handles the three remaining process steps; Hand-Mounted Technology (HMT), Coating & Potting, and Final Assembly. To aid the managers in their work, there are also several operation coordinators working in the different process steps, which help the production managers with daily resource and work planning. The operation coordinators are
also responsible for securing and coordinating inbound material for work orders produced in their corresponding processes.

**Quality**

The Quality department is responsible for managing everything related to the quality of internal processes and production of products, fulfillment of the IPC and medical quality standards as well as managing of the repair department for product repair work.

![Organizational structure of Quality department](image)

**Figure 14 - Organizational structure of Quality department**

The IPC quality standards are set of standards from the Institute of Printed Circuits - Association Connecting Electronics Industries, which regulates the assembly and production requirements of electronic equipment and assemblies. As the company is also certified for ISO13485 the quality department is also responsible for that the company is able to satisfy the production requirements for products which are produced to the medical industry.

The Quality Engineering aims to measure defects in the production and solve the root causes of the problems in order to heighten the quality of the programs. As of today, this process holds the position of one person and the quality engineer therefore has a special focus on customers with high quality requirements, such as medical products, or products which especially suffer from poor quality.

Every problem in the production which is related to the quality of the raw goods and materials is handled by Material Quality. If a material, which used in assembly process throughout the production, is encountered with quality defects it is reported to Material Quality which will start a material problem investigation with the supplier.

The Repair department, which is managed by the quality manager, handles non-conformities of products related to internal processes or customer returns. Any repairs issued from in-line production processes in the production or from customer returns are repaired by the technicians in this department.

The quality manager also holds a daily pulse meeting in the production with the main departments involved with the production, where every defect encountered related to the quality of products and the production processes are reported and followed-up. The aim of these pulse-meetings is to find and correct systematical errors and defects by coordinating the quality corrective work with the persons in the quality processes and key persons from the main production departments.
Engineering

The Engineering department at the company is comprised by three sub-functions; product engineering, process engineering and test engineering.

Figure 15 - Organizational structure of Engineering department

The product engineers are responsible for the planning, preparation and work calculation for new and existing products at the company and they are also responsible for the handling of customer product documents. For the planning of a product, the product engineers plan and set up which operations or process steps a product has go through in order to produce the final product for the customer. The preparation of a product involves design of product specific tools and fixtures and set up of product work instruction documents. The tool and fixture design for product engineers involves in-house manufacturing or purchasing of tools and fixtures needed for box-build. The work instruction documents are set up for all products in order to ensure that the operators produce the products according to the customers' requirements. The final responsibility with work calculation for a product involves calculation of takt-times and resources needed for the production of a product which in turn is used as information for the cost calculation performed by account management. The product engineers are divided by customers and are often responsible for the engineering of products for several customers.

The process engineers perform similar tasks as the product engineers with the difference that their main responsibilities are set to manage the machine processes in each process step of the production. The reason behind the differentiation of engineering work related to products and processes is to secure the quality of the production of products, the processes used in production and to alleviate engineering work load by shared work activities. The process engineers aid the product engineers with the design and manufacturing of process related fixtures and tools, coding of machine programs, fine tuning of processes and set up of machine process work routines for the operators.

The test engineers are responsible for the management, development and coding of all test equipment used in the production. The test equipment used in the production are either customer owned or company owned depending on the customer's own ability in developing test equipment. This means that for some customers and their products, Orbit One AB is also responsible for developing the test equipment’s hardware and software, and securing its quality and functionality, needed for a product in order to fulfill the products testing requirements. The test equipment is often used in the later process steps of the production in order to test circuit connections and/or product functionality. Similar to the product engineers, the test engineers are assigned by customer and are responsible for the test equipment of the products of several customers.
**Purchasing**

The purchasing department manages the company’s material demand for the production of products. Everything from raw product materials to assembly goods is planned and ordered in close cooperation with the planning and account management departments in order to secure the material demand on the basis of product forecasts and customer orders. The purchasing department is in difference to the other departments not differentiated by products and processes. Instead, purchasers are divided by the range of component and materials which are used in the production. In example, this means that one purchaser can be responsible for the purchasing and handling of all printed circuit boards to the products while another one can be responsible for components types such as capacitors or integrated circuits.

**Planning**

The planning department is responsible for the forecasting, work orders and deliveries of products from the customers as well as the daily planning of work orders in the production.

![Organizational structure of Planning department](image.png)

**Figure 16 - Organizational structure of Planning department**

The forecasting of products estimates the upcoming demand for the customers’ products as input to the purchasers in order to secure the material needed for the production. The aim of the planners’ management of work orders and product deliveries is to secure the production and delivery dates in order to prioritize and plan the production of a product and the end delivery to the customer. The daily planning work is an extension of the work order and delivery management which is done in cooperation with the production managers and the operation coordinators. Daily planning meetings are held with the production managers and coordinators to plan the production for the next 48 hours with adjustment to any interferences or issues related to the production processes or product material.

**Logistics**

The logistics department is responsible for both inbound and outbound goods and materials delivered to and from the company.
Figure 17 - Organizational structure of Logistics department

The inbound material and components are processed, sorted and delivered to the internal warehouses related to each production process. Materials used in the surface-mounted processes are sorted to one warehouse while hole-mounted and box-build materials are sorted to their corresponding warehouse. Many assembly stations and hole-mounted processes have their own material supply shelf for frequently used components and materials which the logistics department is responsible for overseeing and refilling continuously. All first time deliveries from a supplier and materials which recently have been encountered with problems related to material quality must also go through an incoming material inspection. The material inspection also takes running samples of other materials to follow-up on the quality of continuously used raw materials used in volume production. This process is closely coordinated with the Quality department and the Material Quality process for input and follow-up on the quality of materials used in the production.

The outbound material handling involves both packaging and shipping of the end products to the customer. There is also a warehouse for final goods inventory for a few customers which the logistics department also is responsible for managing.

Account Management

In the structure tree below can be seen the corresponding processes for the Account Management department. As mentioned earlier, the Account Management department has a dual role in the organization related to the production of products.
Each Account Manager handles one or more “Programs”, and one program includes one customer and all their belonging products which are produced at the case company. Each program is also typically assigned with one Planner as they in their work require a close or direct contact with the customer. The Program Management refers to the management and manufacturing of series or volume production of products for a contracted customer. The Account Managers handles much of the main contact with the customer, quoting of new orders, management of customer contracts and they are also responsible for the program’s economics, such as billing, revenue, and profit margins for products. Together with the Planner, the Account Manager also handles the forecasts of the program’s products and the incoming product orders. All technical feedback on the products quality and functionality from the customer is reported directly to the Account Manager who delegates work activities and corrective product actions to the other engineering or quality departments if needed.

The Account Managers are also responsible for the project management processes at the company.

Any changes to an existing product are issued from the customer to the company as an Engineering Change Request (ECR) which will initiate an Engineering Change Order project (ECO). The aim of these projects is to implement changes to an existing product and secure the internal processes. The scope of the changes may be to improve the products quality, functionality, simply changing to other components for a better total product cost, or all of them at once. They extent of the change varies depending on the complexity and scope of the change but will always result in that the product will carry a new revision in the production when the changes are implemented.

New Product Introduction (NPI) projects are initiated when a new product is introduced to the program’s product portfolio from the customer or when a new customer is contracted to the
company. At the company, the majority of the NPI’s which are initiated are for the already existing customers. The aim of these projects is to secure the internal processes at the company and investigate if any new processes have to be added to the production lines in order to finalize the end product. Most of the already existing production lines and processes at the company are used for new product except the final assembly stages, box-build and testing, as these stages often require the company to develop and purchase new fixtures, tools and test equipment.

An existing product from a customer for which production is subject to be moved from or to the case company’s production facility is initiated as a Transfer Product Introduction (TPI). For a TPI project where an existing product is to move its production to the case company, the scope of the project is quite similar to a NPI project with the main difference being that no new engineering or process development has to be performed for the already existing product. But the existing products processes have to be adapted to the production of the company and the internal processes for the product have to be secured. For a product which production is set to be moved from the company’s production facility, the scope of the project is to phase out existing processes and material and support the new production facility with documentation until the transfer is deemed complete.

As mentioned in the limitations of this thesis, the data collection for the result will only consider NPI projects in the area of project management. As the rest of the processes for the Account Management department are parts of the program management and thus related to the continuous volume production of products, any problems identified in the data collection for these processes will be considered in the analysis of the thesis.
4.3 MANUFACTURING OF PRODUCTS IN PRODUCTION

In order to understand the problems that occur in the production environment, one must first understand the production flow of materials and how the manufacturing is planned and executed for products.

The differentiation of the production set up and production line flow for the case company, and also other contract manufacturers, from other companies in the electronics industry is that the processes produces in a mixed flow for the customers’ products. It is thus only a part of the production flow that is featured as isolated production lines. As seen from the organizational structure, most of the process steps in production are therefore divided by function except the final assembly which includes box-build and testing. The final assembly is instead divided by program, and in turn the customers, as much of the material, tools, fixtures and test equipment are shared and used for the products of one customer.

The figure below explains a simplified flowchart of the material, product and repair flow in the production with all the major assembly stations drawn out. As seen in the figure below, it all starts with the arrival of inbound material. The material is sorted and if necessary inspected before it is shipped out to the internal warehouses. The SMT warehouse contains all the surface-mounted components which are used for the SMT assembly of PCBs. A product is produced in one of the SMT line depending on technical features, complexity, PCB design and the materials used. One SMT line can therefore be used for several different products from different customers. But before a product can begin to produce the production operators first has to kit the material. Kitting refers to the operation of collecting all the material needed for a work order. When the kitting is completed and all material has been collected, the operators flags the kitting operation as completed in the production system. After the kitting, the work order and all the material has to be rigged on the mobile material carriers which is docked and connected to the SMT assembly machines. The amount of available material carriers is limited in amount and are also specific for each machine. When the kitting and rigging of a work order is completed the work order and the PCBs are finally ready to be assembled in the planned SMT line.
Figure 19 - Flowchart of materials, products and repairing in the production
When the SMT assembly is completed, the work order is parked on a trolley in queue for the next operation in the HMT flow. Similar to the SMT production, the work orders have to be kitted with the materials used in the hole-mounted machine assembly. For some products in this step, the number of components which are to be soldered might be so high that the work order needs to be prepared with manually assembly, populating the PCBs with unsoldered components, before they can be soldered in the HMT-machines. Products which are wave soldered, selective soldered, and so on, then enters a specific line in the HMT flow, waiting for the planned job slot in the line queue. If some of the components cannot be soldered in any of the machines, the work order has to be hand soldered before the work order is finished.

Because the SMT and HMT production flows produces the different customer products in the same lines, it presents some planning implications. If a machine related problem occurs in one of the process steps of a production line, it will most likely delay the production for all the work orders which are planned for that specific. However, if a major product related problem occurs in any of the production line the work order is often removed in order to keep the production running. When the problem with the removed work order is solved, it will have to be re-planned and scheduled in the queue of the production line again. Pilot production for new or revised products is also performed in the same production lines as volume production and therefore add to the challenges of planning the manufacturing of products.

When all the soldering of the PCBs is completed, the work ordered can be coated or potted if required by the customer. The work order is relocated to the coating and potting area and the necessary operation is executed. Before the work order can enter the final assembly stage, curing of coating or potting has to occur. It can either be done in a low heat oven or by air, which gives a better result. However, air curing is a slow process and depending on what operation is chosen, it can therefore take up to several days before the curing is completed.

In the final assembly stage, the PCBs are tested for any faults related to components or soldering performance in the ICT test. If no faults are detected the PCBs continues to the box-build operation. Box-building refers to the operation where PCBs are assembled into the final product. As the name suggests, the PCBs are often assembled in enclosures with electromechanical components such as displays, buttons and additional hardware. The box-build can feature a single PCB but there are also end products which are assembled with multiple PCBs. All of the PCBs thus have to be assembled, soldered, and tested before box-build operation can be finished. The FCT test is usually performed last to test the functionality of the final product. The functionality of the PCB(s) and box-build hardware has to be tested together in order to confirm the performance and quality of the end product.

When final assembly is completed the finished products are collected for shipment according to the customer order. The shipment is packed, sorted and sent to outbound material delivery or storage for the customer.

As seen in the production flow chart, there is also a repair flow present in parallel to the production lines. For all PCBs and products where a defect related to poor soldering or faulty component is detected in a work order, the PCBs or products are collected and sent together to the repair department for troubleshooting and repair. When the repairing is completed, the PCBs or products are either sent back to the production line to finish the job or if possible sent to the next production area where to rest of the work order is waiting. Depending on the scope of the faults and defects related to the PCBs or products, this might not be possible and some
work orders will have to remain in the repair department until a new work order with the same product is planned for manufacturing in the production line of target.
4.4 Identified Problems in Volume Production

The following chapter presents the results from the interviews of the identified problems which occur in the volume production of products. The results will be presented by department in the same order as described in the organizational structure.

Production

There are currently two production managers, one for SMT and one for the HMT and the other areas, but works closely together in order to secure a steady production flow. With roughly 60+ people working in the machines in assembly stations, the resources become a critical part of the managers’ job activities.

“My role is very centered around staff planning and resource management, but I also get a lot of help from the operation coordinators to help with this. How we should prioritize work in the most efficient way and how we should distribute our resources. However, we also always have to keep in mind to produce and deliver our customers’ products as smoothly as possible.” – Production Manager

The initial resource distribution performed by the managers and is based on the forecast of next month’s work orders. The daily resource planning is performed together with the operation coordinators for how they should man machines and tests for the next 24 hours. They also hold a daily planning meeting with the planners in order to plan the machine schedules and prioritization of work orders for the next 48 hours in order to maintain to the promised delivery date to the customer. The planners have the responsibility to coordinate both material and product availability in the production and are therefore the ones who determine when a work order is available and is ready to start in production. The planning meetings is an important communication channel for the production and planners to discuss any problems or delays related to the production or material supply.

“It always comes down to the question of prioritization as we have a lot to produce most of the times for different customers. It is very rare that we have a flow with work for only one customer. This results in that we have to prioritize between the different customer programs and any disturbance can create a difficult situation with how the work orders should be prioritized.” - Production Manager

There are many different assembly stations and machines in the production and the job is often performed by one person. The main challenge as told by the production manager in his role is therefore to keep the production in a steady state with the limited resources at hand in order to attain the desired output of the production and prevent any foreseeable disturbances.

“It is always the bottlenecks in the production that creates problems. It always results in a question of prioritization of the work orders and whose customer delivery that is most urgent at the time. It very rare that we have one flow where only one customer’s products have to go through. We have many bottlenecks, sometimes it is the machines and other times it can be complex work tasks which ties up resources which is needed somewhere else.” – Production Manager

Single-sourcing of resources is said to be a problem which the production managers works with continuously and they also work together in order to pool resources and strengthen
sensitive areas. Machine and staff resources are however not the only concern in the production. In the interviews with the people working in the production, material availability often becomes a problem when it comes to planning and executing a work order.

“We have a continuous problem with material shortages which can create a bottleneck flow in no time and it is very hard for us to predict.” – Production Manager

The operation coordinators also have a role with supplying material to the assembly stations, and retrieve and prepare material for work orders that are supposed to be machine assembled. They are often the first ones to know when a problem arises with the material quality and availability.

“Sometimes it can be material shortages that the planner does not even know about. I have experienced such a shortage recently and I had to call the planner and tell them that we could not finish the job. I want to be able to start a job when everything is set up without having half-done work orders that has to be finished later. /..../ If we have not secured the material, we should not be able to start the job. Many times we can receive work orders from the SMT lines where a whole order has been finished even though a component is missing and it often results in that we have to use our resources to finish the work order which can take a lot of time.” – Operation Coordinator HMT

In the interviews with the operations coordinators it is explained that the production itself is the reason that these material shortages occur. As much of the machines and equipment in the production park is old, material tends to get lost in an operation which results in that extra material is used. In the SMT lines where one work order can require a thousand pieces of the same type of component, an extra amount of a couple hundreds of components might not get noticed by the operator.

Improper handling of the material and wrong machine set up by the operators themselves can also lead to that components get bent, broken or faulty which has to be scrapped and extra components are needed for the work order. As it is very difficult for both the operators and the operations coordinators to keep track of how much material that gets lost or is scrapped in the process the total amount of material used in production rarely gets corrected in the material planning system. With no active routine or additional equipment to keep track of the actual material balance of material and components used in an operation, the difference of actual and planned amount of available material balance in the system increases with each work order performed in the production.

Aside from the problems with the material supply, it is also important that the material is prepared and packaged for the right operation. One of the operation coordinators interviewed continues to explain about experienced problems with material preparation:

“We can get components that can be wrong for the operation, sometimes leads of a component can be too long or the can arrive in bulk instead of on a roll.” – Operation Coordinator HMT

When purchasing material for a product an important factor for the usage of the material in the production is the materials specific parameters for certain operations, such as packaging of
the components. To be able to place the components in a certain machine operation, the purchasers has to choose the right packaging that the targeted machine feeder is designed for. If the wrong packaging is ordered, the operators either has to re-package the components manually or wait for a new material order. Preparation of components are also an important part for smoother production. In the HMT and final assembly production where much of the components are manually assembled the preparation of the components can affect the time needed to complete a work order greatly. Cables that are ordered in default lengths from the supplier has to be hand cut by the operators, thus prolonging the time needed for the operation and affecting the quality of the component depending on the accuracy of the operator. Ordering components in bulk is often the cheaper alternative from a purchasing perspective but can also result in that components can get bent, broken or faulty during transportation, again adding to the total scrapping of material in production.

Another problem related to the ordering of material and components is how many component packages are available. As some of the products uses the same type of components in the manufacturing of the PCBs, the quantity of material packages can be a challenge when planning to produce several products at the same time in different production lines.

“The purchasers and I might not see eye to eye on somethings, it might be a cost issue. For example, we might get two rolls of components ordered but I know that we in fact will need at least three of them as the components are used on several work orders. It results in that we cannot produce certain products at the same time.” – Operation Coordinator SMT

The operation coordinators often help the operators with setting up the work orders and prepare material, as with the problems of material availability and material quality, they are therefore the first ones to know when something is missing or if something goes wrong.

“We can have problems with labels that are missing or gets destroyed in the process, machine breakdowns and other technical problems. We often can't resolve these issues by our self. When a problem like these are discovered it is often an acute situation. We cannot wait ten minutes because otherwise the production will be delayed.” – Operation Coordinator HMT

It was told in the interviews that when such issues arise the production has to get the help needed from the department responsible for securing that part of the process. As the employees in the other main production departments work with several different customers at once and work with project and regular production work activities at the same time it often difficult to get the help needed from them. From the interviews with the people in the production, the engineering department was said to be the most difficult department to get help from as they are often pre-occupied with a lot of work.

“In different meetings it was most often the case that people from engineering could not attend. But when they actually could attend, 80% of the time they had to leave the meeting for some emergency situation in the production with problems they had to solve.” – Production Manager

Although both the operation coordinators and production managers confirm that the engineering department often helps out when an urgent problem occurs in production, it is said
that it is much harder to get their help in order to secure or address issues with processes which should have been performed before the products entered volume production. The product engineers and some process engineers are responsible for following the flow of all new products, writing work instructions and making sure that the production process for the product is secured and in order. However, the interviews confirmed that many problems were related to unsecured processes and lack of instructions to processes and work activities.

“We have a lot of problems with missing or incorrect work instructions. We know that the engineers have a lot to do and we do not want to disturb them too much, but I have to. Otherwise the production will stand still.” – Operation Coordinator HMT

Both operation coordinators also confirmed that the production monitoring of new products were rarely performed by the responsible product engineer. Because there exist no previous instructions for new products and it is hard to get the information from the product engineers it could sometimes result in that the products had to wait in the flow until they could get the help needed.

“We got no help, no one came out and showed us how it should be done. And when they finally did, they noticed that the fixture did not even fit in the machine. So we had to wait for that to get fixed as well. /…/ They should be the ones to follow the product flow and instruct us what to do. They used do that before, but they are not doing it today.” – Operation Coordinator HMT

The operation coordinator of the HMT also explained in the interview that a lot of the focus from many of the main production departments is shifted to the SMT production as this is where the production starts. Delays, disturbances and other issues therefore becomes a critical factor for how the rest of the product flow turns out. The operation coordinator continues to explain that pilot production is especially affected because of this focus on the SMT production. Activities are planned in detail for the initial flow of the new product but when it reaches the HMT production the pilot work order falls into the same flow as the other volume products. The lack of information and planning of the rest of the pilot flow results in that the new product gets produced with little or no process follow-up from the NPI project team.

“We used to have dedicated project managers who oversaw these things and followed-up all pilot related activities and processes. /…/ For new products it is especially important to follow-up on the whole flow.” – Operation Coordinator HMT
Table 5 – Summary of identified problems from Production

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<th>Identified Problems from Production</th>
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<td>Material quality</td>
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<td>Material supply</td>
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<tr>
<td>Problem follow-up</td>
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<tr>
<td>Process and product securement</td>
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<tr>
<td>Production monitoring of products</td>
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<tr>
<td>Prioritization of work orders</td>
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<tr>
<td>Resource capacity</td>
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<tr>
<td>Resource planning</td>
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<tr>
<td>Securement of material parameters</td>
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<td>Work instructions</td>
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Quality

The quality engineer at the company works with much of the problems and defects which are identified for processes and product in the production. When describing the quality work at the company it was described that much of the quality work was to give attention to problems in a reactive way. The quality engineer described that much of the operators and engineers are experienced with the processes but even though the people working in the main production departments know about the process weaknesses and problems which usually occur, it is seldom anyone who do anything to prevent predictable errors and problems.

“Sometimes when I work with a quality issue, I can go through old reports and notice that one of the engineers have already identified the possibility that the problem could occur. But no one had followed-up on it and addressed it.” – Quality Engineer

The quality engineer continues to point out that follow-up on problems and preventive measures are often lacking, from operators up to managerial level. The reason behind this is told to be that much of the focus is always on the next job. A product is produced and if a problem occurs in the process the production and the other departments does their best to fix the product to a functional condition, but when the product is finally delivered to the customer the focus has already shifted from what could be done better next time to what product is going to be produced next. The quality engineer continues to explain that a big issue which causes this situation is that the customers to contract manufacturers rarely wants to pay extra for engineering analyzes and activities which drives up the final costs of the products. The work performed by the contract manufacturer for the customers’ products is simply reflected by what the customer is willing to pay for. In some projects and quality cases these engineering analyzes, such as DFM, risk analyzes and quality defect control, is said to give a 50/50 result for the end product. Sometimes these early product analyzes produces nothing, resulting that in an unnecessary cost for the customer. However, in the cases where the analyzes have resulted in detection of systematical errors, early preventive measures and possible problem outcomes which can be prevented, the customer’s product have been noted to achieve a better quality of the end product with less process disturbances. The quality engineer continues to explain that it many times comes down to the company’s mindset and strong focus on customer
service and flexibility, producing what the customer requires. The strong customer focus has resulted in that the company does not consider the internal requirements which could lead to better production quality. Performing internal risk and quality analyzes is mentioned as measure which could result to a better production performance and improved quality of the customer programs.

Table 6 - Summary of identified problems from Quality

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<th>Identified Problems from Quality</th>
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<tr>
<td>Internal risk and quality analyses</td>
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<tr>
<td>Problem follow-up</td>
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</table>

Engineering

The product engineers as mentioned is deeply involved with supporting the production at all times and supporting the other departments with technical information about the products which are produced for the contracted customers. In the interview with one of the product engineers the work load of the product engineers was pointed out as an issue in their work. The product engineer which was interviewed was at the moment assigned to the products of seven different customers and was aware that the high workload affected the quality of the engineering work. The product engineer proceeds to tell that product engineers are aware that some of the products in production have minimal of no work instructions available because of the lack of time to address these work activities.

““You need more time because of all the customers and the work you have to do in parallel. If the workload is too much, things such as work instructions get lower priority. There are fixtures, screen plates, tool and programming that needs to be designed and that is what gets highest priority.” – Product Engineer #1

Aside from working with the regular engineering activities related to the products they also have the responsibility of helping the production when an urgent problem occurs with a product which in the interview is said to affect the engineering departments workload as well.

““There are always some kind of disturbance or issue that you have to attend to, which makes it hard to pick up where you left off.” – Product Engineer #1

The product engineer also states that the difference of how the customer wants the company to manage the customer documentation and in what format the documentation is available also affects their workload. Some of the customers use external servers which the product engineers have to access remotely in order to obtain all product documentation. Others provide drawings, 3D-models, and even verbal information to cover the information of the product. As every customer has different methods for providing the documentation it can take considerable time to secure everything for the product and the product engineers often have to convert a lot of the documentation from an internal standard in order to ensure that all product engineers can read and understand all customer product data.

The high workload and time pressure to secure every technical aspect of a product results in that they often do not have the time follow-up on every activity. The product engineer explains that they because of the lack of time often relies on others to get the information of how the
production run went. This is however also explained only a part of the problem with the lack of follow-up on a production run. The product engineer states that for the following processes they often do not have the same ability to follow the product and there is little help to get from other departments. It is explained that the time delay between the start of the processes and the constant rescheduling because of disturbances is a factor which affects their ability to follow the production run. In some cases, the products can already have gone through a process step which were supposed to be documented and the product engineer then has to interview the operators in order to get any input on how the production went. For pilot productions where much of the information about the production of a product goes into the pilot report to the customer, the lack of firsthand information from the production affects the feedback which is sent to the customer. When asked about what causes the delays and the rescheduling of work orders, the product engineer mentions that they are often related to issues with materials. For pilot productions, the components often get delivered the same day that the product is planned to start in the production and if the material is not available on time the scheduling of the production can be delayed for a day or two.

In the interview with one of the process engineers much of the already explained problems from the product engineers were confirmed. A lot of the reoccurring problems for the process engineers were either related to the machinery in the production or issues related to the materials. The old machinery constantly need tuning and adjustments from the operators and if the problems were too severe to handle, the process engineers were often contacted to assist the production. Another problem was that the material also affected the machines. Variances in material and component quality resulted in that no production run could be expected to produce the same result, and much of the result relied on the experience of the operators. One problem which were difficult to control was the processes that relied on automatic vision data in the material feeders. The variance in dimensions between two component suppliers could be so different that the vision-equipment registered the components as faulty, leading to unwanted scrapping in the process. The machine therefore has to trained to learn this component variance manually by the process engineers in order to prevent this problem.

The process engineer explained that the suppliers of components are often approved from the customer at the NPI stage with a list of approved manufacturers, a so called AML (Approved Manufacturers List). The purpose of the AML is that there should not be any major difference between the components regardless of supplier and in the pilot production the process is therefore only secured for one supplier of components. However, when the purchasers later on changes to another supplier there is then the possibility that there could be a variance in the material that affects the process.

Another problem stated by the process engineer was that the lack of securement of new products and follow-up on project work activities could lead to that many problems related to new products were discovered first when they enter volume production. As the design of the products are often set for the customer when the products ramp up, any feedback and suggestions of fine tunings to the customer’s product design, in order to improve the manufacturability of the product, are thus not possible for the customer to incorporate. It is not until the product is revised or a next-generation product is ordered that the changes can be incorporated. Much of the intensity and high workload in NPI projects depends on how quickly the customer wants the product to enter the market. For the customers, the aim of the projects is often the matter of receiving a fully functional product which is ready for the market and it is
rare for the customer to quote for a pre-series production in order to ensure the maturity of the product’s design and functionality.

“We often achieve good results with pre-series, as the customer expects that they will be able to perform changes in these scenarios to further improve the product.”
– Process Engineer

The process engineer continues to explain that the customer instead prefers to run several pilots before they decide on the final design of the product. Execution of several pilot projects do enable the company to perform better but as the final design it decided by the customer the production has no way to know which of the prototypes that will eventually become the final product. When the design is decided by the customer and the product ordered for volume production the ramp-up process still becomes very short for the company.

In the interview, the process engineer also confirms the problem with the lack of feedback from the pilot production for some products but also explains how the lack of information can lead to further implications for the financials of a program. If a process related problem occur in the pilot production, it can lead to that the operational flow of the product has to be changed, such as adding an additional operation, in order to finalize the end product. As the quote of the new product is often based on an optimal operational flow or existing products with similar operations, these changes has to be reported in order to correct the quote. If the operational flow of a new product is not verified before the product enters volume production, the actual operational flow of a product will result in that the total cost of the product is higher than what is billed to the customer.

Table 7 - Summary of identified problems from Engineering

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<tr>
<th>Identified Problems from Engineering</th>
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<tbody>
<tr>
<td>First-hand information from production</td>
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<tr>
<td>High workload</td>
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<td>Material quality</td>
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<tr>
<td>Problem follow-up</td>
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<tr>
<td>Production monitoring of products</td>
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<tr>
<td>Product’s readiness for ramp-up</td>
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<tr>
<td>Unreliable machines</td>
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<tr>
<td>Unknown actual production performance</td>
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<tr>
<td>Variation of customer documents</td>
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Purchasing

It was acknowledged in the interview with the purchaser and the manager of the purchasing department, that the company had problems with material shortages and incorrect material balances. This had been a historical problem that the company had learned to control to some extent. The purchasers print out a daily shortage list of the material they are responsible for in order to take action before it affects the production. Correcting the problem takes up to several days and many times it could lead to that SMT material rigs are sustained in production when the rig could otherwise be used for another work order. If the material delivery is too long, it could even result in that the material rigs have to be torn down and many work hours are lost for nothing.
In the interview, the purchaser confirms that the machine park itself is part of the problem with the material shortages but also states that it is connected to increases of customer orders. As much of the material is ordered based on forecasts and order promises from customers, a sudden order increase will thus generate material shortages. This triggers an event where the customer and the case company together has to coordinate material orders with the suppliers in order to ensure that the material gets delivered before the planned start of production. This event is known to the purchasers as a “load & chase” scenario, where the purchasers start to load the system with new material orders and then chase home the material deliveries. The material lead times and material availability of the suppliers becomes a critical factor to this scenario and is what ultimately determines the outcome.

The purchaser confirms that they from time to time experiences different problems related to the customer AML. Sometimes the components listed in the AML can be wrong but another problem is that the complete information about the components can be missing, such as choice of packaging. The customer often specifies which brand of component but many times leaves out if the component should be delivered in packages of rolls, sticks or trays, which depends on which machine process the components should be used in. The packaging type of components should be determined for every new product during the NPI project phase, prior to the ramp up to volume.

“We do not have this kind of cooperation with engineering and the production where we sit down and discuss; ‘Which kind of packaging do we want for these new components?’” - Purchaser

The purchaser believes that many of the purchasers does not have the knowledge to determine this on their own and that many of them does not ask for the information about the packaging either. It is only when the production informs the purchasers that the packaging type is not fit for the operation in the production, that the component information gets changed.

This kind of feedback, with comments on the material, from engineering and the operators in the production is supposed to be communicated through the pilot report resulting from the pilot production, at the summary meeting in the final phase of an NPI project. The purchaser explains that this meeting is rarely held due to lack of time in the projects and with no feedback between the departments, the problems does not reach the responsible department until the product has entered the first volume production run.

Table 8 - Summary of identified problems from Purchasing

<table>
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<tr>
<th>Identified Problems from Purchasing</th>
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<tr>
<td>Correctness of AML</td>
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<tr>
<td>Material supply</td>
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<tr>
<td>Securement of material parameters</td>
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<td>Sudden order increases</td>
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</table>
Planning

For the planners, the available resources planned for next month’s work order forecast is a critical factor for the production planning. The resource capacity requirement based on the forecast are distributed evenly but when the actual orders are confirmed, the customer demand can be higher at the beginning or end of the month. The demand uncertainty leads to that more resources are needed, sometimes exceeding the available resource capacity in a process. Borrowing resources from other processes is not always possible and there is also the risk that resources taken from one process to secure the production of one product may cause delays for another.

The biggest issue for the planner with satisfying the customer’s demand requests and service level is said to be the insecurity with the product’s through-put time in the production. Re-occurring delays and disturbances in the production often lead to that the planners have to renegotiate the delivery date with the customers.

“I do not have any difficulties with delivering to the promised minimum customer demand, but delivering based on what the customer wishes for can be difficult sometimes.” – Planner

Very few of the customers have a safety stock for their products, which means that many products require a smooth production without problems such as delays and quality defects in order to satisfy the customers.

The planner continues to explain that the mixed product process areas in the SMT and HMT affect the company’s ability to produce a product on a certain lead time greatly. The biggest bottleneck for the planner is however the SMT production and any late material delivery, lack of resources, or quality issue can cause delays which increases for every following operation along the product flow. The planner states that the material shortages and incorrect material balances is what affects the company’s production the most. The initial processes in the SMT production area is heavily dependent on the material availability and the shortages together with quality issues and machine breakdowns often cause delays for all the customer programs.

The planner explains that the personnel working directly with the production of products often has a better understanding for the actual through-put time of products but with the lack of feedback between departments, internal process securing with new products, and re-occurring product and material issues creates a disconnection between the expected and actual through-put time of products.

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<th>Identified Problems from Planning</th>
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<tr>
<td>Production disturbances</td>
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<tr>
<td>Resource capacity</td>
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<td>Variation in product through-put time</td>
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</table>
Account Management

In the interviews with the account managers there is a consensus which confirms many of the mentioned problems by the other main production departments. The account managers are aware that disturbances and delays are a common experience for many programs which affect the program financials, customer service levels, and end product quality.

The account managers mention that product complexity is a crucial factor for the programs quality and relates to the learning of production. The higher the complexity of a product the longer it takes for the program and the production to learn the processes connected to the product. For some products it can take a whole generation until the product reaches full maturity and achieves a steady production. As the NPI projects are often very short with a high focus on early product launch there is often no possibility to ensure that the learning is sufficient.

As the account managers has to put a lot of the focus towards the customer in their job and the management of the program as a whole, much of the responsibility regarding the technical aspects of a product is delegated to engineering and the other main production departments. The dependence on the other departments for the technical work results in a that the account manager’s becomes even more disconnected from the production and further complicates the account manager’s ability to follow-up on the actual production performance for the customer’s products.

Table 10 - Summary of identified problems from Account Management

<table>
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<th>Identified Problems from Account Management</th>
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<tr>
<td>Internal process measurements</td>
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<tr>
<td>Product’s readiness for production</td>
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<tr>
<td>Unknown actual production performance</td>
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4.5 NEW PRODUCT INTRODUCTION PROJECTS

The new product introduction at the case company is often initiated by customers which are already contracted to the company and part of the existing account management programs. Therefore, it is often the account manager of a customer program that manages the projects issued by the same customer. As with the program management the scope of the NPI projects varies depending on what kind of product the customer requires. The project activities featured in a NPI project are thus unique for each project. There are however some activities and level of management that are standardized for a general NPI process as seen in Figure 20.

![Figure 20 – General NPI process at case company](image)

When a project has been approved by the management board and the customer documents are available the projects is initiated with a project kick-off. In this step, project work is broken down, an initial project plan is formed and the members of the project team are selected. If applicable, a project manager is also elected to manage the project.

The project start-up is held in the form of a meeting where the planned project work is discussed in the project team. Any risks or circumstances which may affect the project plan is discussed at the meeting before the project work is initiated.

The project work is what varies depending on the scope of the project. General tasks and responsibilities which are typically featured in a project can be seen in the figure below. As can be noted from the figure is that most activities are planned in relation to the planned start of the pilot production, which in the project plan is mentioned as “Day Zero”. Activities prior to day zero are often related to engineering, purchasing and planning tasks to ensure that fixtures, process tools, and components are secured and available at the start of the pilot production.

![Figure 21 - Example of NPI project at case company](image)
At day zero, when the pilot production is started, the pilot production is carried out by the production processes with engineering and quality present in the production to secure and monitor the products manufacturability and quality.

When the pilot production is completed and the pilot order has been delivered, the departments gather the feedback on the performance of the pilot production. The project team is then summoned to a summary meeting where all feedback is shared among the members in the project team and the project manager. Problems encountered in any of the internal processes during the pilot production are taken care of with a list of action points which are delegated by the project manager to the process responsible department.

After the summary meeting, the product engineer gathers all feedback and suggestions of fine tuning related to the customer's product design into the pilot report. When the pilot report is approved by the project manager, the report is sent to the customer. After the pilot report, the project manager follows-up on the list of corrective actions to oversee that they have been completed and implemented. When the pilot has been approved by the customer, a factory approval is sent to the customer stating that the product is ready for volume production at the company.
4.6 INFLUENCING FACTORS IN NPI PROJECTS

The following chapter presents the results from the interviews of the identified factors which influence the performance of NPI projects. The results will be presented by department in the same order as described in the organizational structure.

Production

When questioned about the production's direct involvement with NPI projects, the operation coordinator in the HMT states that the information regarding the planning and production of pilots in the production are often poorly coordinated with the operators and the operation coordinators. For operation coordinators, the information received regarding new pilot production are mostly shared at the daily planning meeting with the planners. The operation coordinator describes that the short notice on pilot production gives little time for the responsible processes to coordinate their resources accordingly.

The HMT coordinator continues to explain that there used to be dedicated project managers managing the NPI projects in the organization. These project managers were only tied to project management and dedicated to the introduction of new products from customers. With a sole focus on the management of NPI projects, these project managers were often more active and committed to the pilot production and often planned and coordinated the required operations of the pilot production more clearly with the managers and operations coordinators in the production. Furthermore, those with managing responsibility in the production who are affected by the pilot production were often involved earlier in the NPI projects, often at the project start-up.

Both of the operations coordinators in the interviews confirmed that the monitoring of the pilot production by the product engineers and project managers is poorly executed. It is experienced that there is an expectation that the monitoring is performed autonomously and that feedback on the pilot production run should be provided at request.

Another issue related to the pilot production, as described by the SMT coordinator, is that much of the new material used for pilots are ordered as samples. The low quantity and often poor packaged components complicates the operation of material rigging resulting that more time is often spent on the preparation of the material than securing process.

Table 11 - Summary of identified factors from Production

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<th>Identified Factors from Production</th>
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<td>Cross-functional production planning</td>
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<td>Project involvement</td>
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<td>Project manager commitment</td>
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<td>Material samples</td>
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Quality

In the interview with the quality engineer it was discovered that the quality department is not currently involved in projects at all and have not been for some time. The quality engineer that the quality department used to be responsible for a basic quality assurance of the products during the pilot production, often performed as an ocular inspection of the products quality related to the processes in the SMT production. The quality engineer continued to explain that for this purpose also exists a quality assurance report tied to each project but is rarely filled out.

Despite the current absence from project activities the quality engineer had participated in many previous projects and could thus share his experiences of the quality departments historical involvement in NPI projects.

The quality engineer described that the purpose of the quality departments project involvement has been to identify any quality defects related to the pilot product. The problem with identifying quality defects in the pilot production of a new product is however that the volume sample is too low in order to confirm any systematical errors. In order to confirm any systematical errors or design issues related to the product, the performance of a pre-series production is required.

When asked about how NPI projects manages requirements, targets and costs related to the quality for new products, the engineer explains that there is little attention given to these factors in projects. The realization of how these should be handled often appears later in volume production if the customer is not satisfied with the quality of the product. The KPI:s and targets used to measure quality of products in volume production is not connected to quality targets in projects. Quality targets in projects are often centered around test equipment and the customer’s requirements regarding test yields. Even though the occurrence of product defects can never be ruled out for any process, the costs and work required to produce a certain level of quality for a product is rarely discussed with the customer on a project level. Although there exist methods through the IPC standards to estimate costs and work needed to assure a certain quality yield for a product, it has never been used to verify the quality of products to date.

The quality engineer recognizes that there do exist a high awareness of quality in the company, but it is mostly centered around the SMT. Even though the operators and process engineers continuously work with solving the quality defects related to the machines and products in this process, the quality engineer states that the company is not very capable when it comes to following-up on corrective actions, especially in NPI projects. Quality engineer experiences that monitoring and follow-up is almost non-existent in NPI projects. The projects often fail to compile a complete pilot report and a list of corrective actions for identified defects related to the project. In the cases where the pilot report is performed accordingly the follow-up on corrective actions is still often neglected.

The quality engineer describes that there is always a notable pressure to deliver and the time plan is often very short in projects. The extreme time pressure results in that proper quality work is sacrificed for the benefit of realizing a product on time.
"Many times the customer is so dependent on the product, as a part of a bigger project, which results in that more focus is put on deliver a functional product rather than a good one." – Quality Engineer

The quality engineer continues to explain another factor which affects the overall project quality is the high flexibility towards the customers. The company has contracted customers which have a high internal quality awareness and often have higher demands for new products. These projects often get a higher organizational focus and support from top-management, with the result of better project performance as more resources are allocated to these projects. With lower requirements from the customer the focus and support to projects are also lowered in the organization.

Table 12 - Summary of identified factors from Quality

<table>
<thead>
<tr>
<th>Identified Factors from Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of internal process requirements</td>
</tr>
<tr>
<td>Follow-up on product’s ramp-up quality</td>
</tr>
<tr>
<td>Linkage between quality targets in projects and production</td>
</tr>
<tr>
<td>Product quality specifications from customer</td>
</tr>
<tr>
<td>Priority of quality focus on processes</td>
</tr>
<tr>
<td>Project involvement</td>
</tr>
<tr>
<td>Ramp-up volume</td>
</tr>
</tbody>
</table>

Engineering

The product engineer describes that the most influencing factor for the project work is the varying degree of extent and status on customer documentation. The completeness and amount of information available through the customer documentation is what affects the outcome of the product engineer’s ability to secure all project activities within the project time frame. If some documentation is missing at the start of a project or if some information is unclear, the product engineer has to put considerable amount of time with the customer in order to obtain the information which is needed to secure the engineering tasks. The product engineer explains that in some cases the design for certain technical aspects of the product might not even be ready and decided by the customer. This leads to that the product engineer will receive information and documentation over the course of the project, prolonging the time needed to complete the engineering activities substantially.

The product engineer confirms that the high workload and time pressure in projects does affect the product engineers’ ability to monitor the pilot production. However, these factors are not the sole reason that the pilot production is poorly monitored. A major part of the planning of the pilot production is only focused on the SMT flow, but for the following operations and processes the planning is never as detailed as for the initial processes. The product engineer describes that from the moment the pilot production is completed in the SMT, the production planning is taken care of by the planners and the production with minimal involvement from other project members which might be affected by the rest of the flow. It is only when it is discovered that engineering support is needed for an operation that the product engineers are informed by the production.
As a result, debriefing on the performance of the pilot production and how it went is therefore insufficient. Only major defects and problems are reported, whereas opportunities to identify possible process improvement and measure of the actual operational performance are lost. This in turn, leads to that the verification of the actual production flow and total cost of production for the new product becomes unreliable.

It is confirmed in the interview with the process engineer that customer documentation is seen as the main factor which affects project work for the engineering department the most. The process engineer explains that the NPI project model and the generic execution of projects performed by the management at the company is not designed to take the product’s complexity and level of available technical information into account, which inherently results in the constant experience with lack of time in many projects.

The process engineer also explains that a causing factor to the poor management and performance of NPI projects is the lack of a proper project ending. Summary meetings are often forgotten or cancelled, resulting that the project team loses the ability to exchange important feedback and for many project members it becomes unclear when the project is determined as finished.

Table 13 - Summary of identified factors from Engineering

<table>
<thead>
<tr>
<th>Identified Factors from Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-functional production planning</td>
</tr>
<tr>
<td>Extent and readiness of customer documentation</td>
</tr>
<tr>
<td>Product complexity</td>
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<tr>
<td>Project closure</td>
</tr>
<tr>
<td>Project meetings</td>
</tr>
<tr>
<td>Verification of actual production flow</td>
</tr>
</tbody>
</table>
Purchasing

In the interview with the purchaser, it is described that for the purchasers working in projects that their project work depends heavily on the how much new material is needed for the new product and the completeness of information in the AML.

As an AML from the customer provides information about the component’s functional parameters, packaging and preferred supplier it becomes a crucial factor for the purchaser’s project work. For every bit of material information that does not exist and for every new component which is unique for the new product, the purchaser has to spend considerable time in order to secure the product material and will prolong the time it takes to order material for the pilot production. As the level of material information is often unknown for the purchaser at the start of a project, it is crucial that the purchaser receives feedback on the material from the pilot production in order to secure the material information of the new product before the project ending.

However, in many of the projects which the purchaser had been involved in, the summary meeting had been cancelled or skipped for reasons unknown to the purchaser, thus complicating the purchaser’s ability to gather all feedback needed to complete the material information before the project is ended.

Table 14 - Summary of identified factors from Purchasing

<table>
<thead>
<tr>
<th>Identified Factors from Purchasing</th>
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</thead>
<tbody>
<tr>
<td>Amount of new material for product</td>
</tr>
<tr>
<td>Information in AML</td>
</tr>
<tr>
<td>Project meetings</td>
</tr>
</tbody>
</table>

Planning

The planner’s involvement and project work is often independent from the other main production departments through the course of the project. A factor which often affects the planner is the final cost of the pilot production, which the planner is responsible to deliver to the customer. The cost of the pilot production is supposed to be calculated and verified by the project manager and handed over to the planner at the end of the project. The planner explains that the lack of monitoring and collection of information on the pilot production results in low ability to provide a correct invoice to customer. The lack of verification of the processes, often result in that the company ends up producing pilot products to a cost which is higher than was initially quoted. If not corrected during the project phase, the costs are difficult to correct with the customer and will directly affect the financials of the volume production of the new product.

One of the activities performed by the planners in the NPI projects is the planning of the pilot production together with the production managers and coordinators. As the pilot production is performed in the same flows as volume production products and products from all customers, the mixed processes can have a considerable effect on the planning of the pilot production. Production disturbances caused by the planning of other products is a common factor which has to be taken into consideration for a good planning of the pilot production.
The planner describes that the NPI project performed at the company often have a good initial focus in start of projects by both the project team and the project manager. Over the course of the project, the focus decreases which results in a weak project ending and the projects often lack a proper closure. The planner explains that the customer expectation and demand of fast product delivery also affects how the project managers manages the projects. When the pilot production is completed and the new product has been delivered the expectation from the project manager is that everything has gone correctly and the customer will be satisfied. If nothing negative if reported from the customer, the project has been executed to plan and can thus be seen as ended.

Table 15 - Summary of identified factors from Planning

<table>
<thead>
<tr>
<th>Identified Factors from Planning</th>
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</thead>
<tbody>
<tr>
<td>Project closure</td>
</tr>
<tr>
<td>Mixed product processes</td>
</tr>
<tr>
<td>Verification of production cost</td>
</tr>
</tbody>
</table>

Account Management

In one of the interviews with the account managers it is acknowledged that the project model and NPI process layout for projects relies on complete information in customer documents and there exists little knowledge internally what the customer documentation should cover in order to confirm the appropriateness of the project in terms of time plan and scope. The account manager explains that as acting project manager, they should feel the responsibility that account managers should take the time to discuss what information the company needs from the customer before the start of a project. But the account manager explains that this perception is not shared with the other account manager many of them are of the opinion that if the customer does not pay for it, it should not be performed.

The account manager continues to explains that the project management has the responsibility to identify potential products risks which can affect the company’s internal processes in the initial project pre-study, but with the current NPI process and the company’s top-management of projects this is rarely performed for any of the NPI projects.

In the interviews, the account managers explain that no program is managed the same as there exists no detailed work procedures or standardization of how projects and programs should be managed. They believe that a standardization of the management could help to improve the internal efficiency and program coordination at the company although it could imply a trade-off for the need of flexibility to satisfy the customer requirements.

Another factor which affects the project management is said to be the company’s organizational structure and layout of the departments process responsibilities. Many departments have dual roles with involvement in both project work and daily production. Not only does the dual responsibility lead to increased work load, but with constant problems appearing in the production which might need immediate attention it also affects the company’s process efficiency. For the account managers, the dual role as account managers and project managers is said to inhibit them to put enough time into projects although they are aware that proper project management needs to be performed with active management and follow-up. As the majority of the company’s revenue and profit comes from contracted customers and volume
production, the program management has a stronger organizational focus from the top-management. This prioritization on program management has therefore lead to that project management has become a passive role where the project managers have to rely on project automation and self-responsibility from the project team.

The account manager also explains that it has become a custom in the company to let the customer decide the scope of the projects with the implication that the company often neglect the internal minimal requirement for the company to secure a functional business model and the requirements for a smooth working production. In order to compromise for this factor and retain a high customer flexibility the company strive for early initial involvement with the existing customers’ development of new products. Thus keeping the projects short and the scope to a minimum while still being able to influence the customers design process.

One of the interviewed account managers reflected and compared the current situation with a past employment as a project manager for another company. The account managers mentioned that one of the factors with poorly executed projects is tied to the organizational project culture. Projects are often seen as a supportive service as part of the company’s standard offering and it is also reflected in how line manager coordinates the resources to projects. The account manager states that proper resource allocation for projects are non-existent. When a project is initiated the project managers are often granted to select and assign resources from the different departments, but it is never known for the project managers how much time is allocated towards the project for each resource. The account manager that it becomes apparent that many of the resources assigned to the project team in fact has the available time to perform the projects correctly.

Table 16 - Summary of identified factors from Account Management

<table>
<thead>
<tr>
<th>Identified Factors from Account Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of internal process requirements</td>
</tr>
<tr>
<td>Customer flexibility</td>
</tr>
<tr>
<td>Extent and readiness of customer documentation</td>
</tr>
<tr>
<td>Project initiation</td>
</tr>
<tr>
<td>Project priority</td>
</tr>
<tr>
<td>Project risk management</td>
</tr>
<tr>
<td>Organizational project culture</td>
</tr>
<tr>
<td>Resource allocation</td>
</tr>
<tr>
<td>Roles and responsibilities</td>
</tr>
<tr>
<td>Standardization of work procedures</td>
</tr>
</tbody>
</table>
4.7 ADDITIONAL PROJECT DATA AND DATA SUMMARY

The NPI project are managed by an internally developed project management tool where it is possible to set and assign the project activities connected to a time line. The activities are assigned to one of the project members which is responsible for carrying out that activity. When the activity has been finished, the project member assigns the activity with a completion status and reports any feedback to the project manager in the software. Through this software it was possible to collect data on projects and activities from projects performed over the last year. All persons at the company which had been interviewed for the study explained that the software was considered as very helpful as it was easy to overview which activities everyone was assigned to and how they were located in the project time line. Some of the interviewees however expressed that follow-up and feedback communication through the software was handled poorly by the project managers.

In an attempt to find data from the software which corroborate with the qualitative data from the interview, information about the projects and their activities were gathered to overview how the recent year’s projects had been executed at the company. The figure below includes data on the completion status of all activities from the featured projects. As many of the projects were executed the same way with the same timeline for activities it was possible to compare the projects based on the project timeline. The activities are sorted on a timeline by when they occur in the project in relation to the start of the pilot production (Day Zero). As can be seen from Figure 22, the amount of completed activities diminishes for the measured projects towards the closing phase of the projects.

![Project activity completion over time](image)

**Figure 22 - Completion of project activities over time**

This information goes in accordance with the findings from the interviews that the projects often has a strong initial focus but decreases over course of time in the projects.

The interviews show that many of the departments experiences minor and major problems which has varied effects for the department themselves and cross-functional effects which can lead to ripple effects across the departments with different outcomes on the work processes and production performance. The same can be seen for the factors as many of them are described as co-dependent. A summary of all the identified problems and factors can be seen in the table below.
### Table 17 - Summary of identified production problems and project factors

<table>
<thead>
<tr>
<th>Production Problems</th>
<th>Project Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctness of AML</td>
<td>Amount of new material for product</td>
</tr>
<tr>
<td>First-hand information from production</td>
<td>Awareness of internal process requirements</td>
</tr>
<tr>
<td>High workload</td>
<td>Cross-functional production planning</td>
</tr>
<tr>
<td>Internal process measurements</td>
<td>Customer flexibility</td>
</tr>
<tr>
<td>Internal risk and quality analyses</td>
<td>Extent and readiness of customer documentation</td>
</tr>
<tr>
<td>Material quality</td>
<td>Follow-up on product’s ramp-up quality</td>
</tr>
<tr>
<td>Material supply</td>
<td>Information in AML</td>
</tr>
<tr>
<td>Prioritization of work orders</td>
<td>Linkage between quality targets in projects and production</td>
</tr>
<tr>
<td>Problem follow-up</td>
<td>Material samples</td>
</tr>
<tr>
<td>Product’s readiness for production</td>
<td>Mixed product processes</td>
</tr>
<tr>
<td>Production disturbances</td>
<td>Organizational project culture</td>
</tr>
<tr>
<td>Production monitoring of products</td>
<td>Priority of quality focus on processes</td>
</tr>
<tr>
<td>Resource capacity</td>
<td>Product complexity</td>
</tr>
<tr>
<td>Resource planning</td>
<td>Product quality specifications from customer</td>
</tr>
<tr>
<td>Securement of material parameters</td>
<td>Project closure</td>
</tr>
<tr>
<td>Sudden order increases</td>
<td>Project initiation</td>
</tr>
<tr>
<td>Unknown actual production performance</td>
<td>Project involvement</td>
</tr>
<tr>
<td>Variation of customer documents</td>
<td>Project manager commitment</td>
</tr>
<tr>
<td>Variation in product through-put time</td>
<td>Project meetings</td>
</tr>
<tr>
<td>Work instructions</td>
<td>Project priority</td>
</tr>
<tr>
<td></td>
<td>Project risk management</td>
</tr>
<tr>
<td></td>
<td>Ramp-up volume</td>
</tr>
<tr>
<td></td>
<td>Resource allocation</td>
</tr>
<tr>
<td></td>
<td>Roles and Responsibilities</td>
</tr>
<tr>
<td></td>
<td>Standardization of work procedures</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production performance</td>
</tr>
<tr>
<td></td>
<td>Verification of production cost</td>
</tr>
</tbody>
</table>
5 ANALYSIS

This chapter presents the analysis of the empirical findings. The analysis is performed through the structure of the analytical model as described in the frame of reference. The initial chapter of the analysis goes through the problems identified in the volume production and how they are connected to the sources of disturbances in the new product introduction process. The next chapter presents how the identified factors are linked to the product introduction process disturbances with the use of the connected theories for the different areas of project factors.

5.1 PROBLEMS CONNECTED TO THE NPI PROCESS

The identified problems from the data collection findings features several problems which are interconnected and confirmed by different departments. The initial part of the analysis is to link them together with the sources of disturbances as presented by Javadi, et al., (2016).

Product

As described by the engineering and account management department, the approval of when a customer product has reached a sufficient volume production maturity is performed as the last activity in the final phases of a process ramp-up. In the NPI process, this is represented as the company’s factory approval. Although there exist certain criteria which should evaluate certain technical product and process aspects as basis for this approval, many of the products in the programs are reported with inadequate production maturity. As stated in the interviews with the account managers, some programs also experience customer products which does not reach a satisfactory maturity until the end of the product life-cycle and the entry of a new product generation. Determining when a product has reached sufficient maturity to enter volume production is part of the NPI process’ last activity factory approval, FA. Based on the pilot report and the customer’s feedback on the product functionality, the product engineer and the project manager should reach the decision if the product is indeed ready for production or if further ramp-up production, such as pre-series, is required in order to ensure a good enough product maturity.

The planning department reports that the production disturbances affect the ability to set a proper production plan greatly. As the production processes feature mixed customer processes the disturbance of one product is not isolated for that program but affects the product of every program which produces in the same process. Production disturbances can be considered as an external factor which might affect the pilot productions. However, it must also be noted that all products which are produced at the company at some point has been introduced as a new product through NPI projects. The outcome of the pilot production themselves therefore has to be considered in relation to the production areas which involves mixed customer processes and how the current performance of a new product will affect the future performance of the production system.

Both the production and the process engineers confirm that the monitoring of products throughout the production is a big concern for the production performance. The production explains that the lack of monitoring of new products often lead to deferred problems with products in volume production which requires support from product engineers. The production and process engineers both confirms that the lack of production monitoring of new products are lacking. This is a problem which is connected to the product engineers’ ability to acquire
first-hand information from the production. For NPI projects is can become a serious problem if the product engineers do not monitor the production of new products, which in turn can result in that the new product in fact is not properly secured when a project is ended.

The production reports that the lack of correct or sometimes even existence of work instructions greatly affects the company’s ability to manufacture products of required performance. Proper work instructions must exist for each process and product in order to ensure that the products are produced the same way, every production run. Work instructions are one of the tasks which the product engineers have to perform and secure for the introduction of a new product at the company. In the interviews, the product engineers themselves explains that the current lack of work instructions in the production processes be traced back to inadequate securement of the NPI project activities.

As explained by Javadi, et al., (2016) it is important for the company to consider the requirements and limitations of the production and product’s specifications in the initial phase of the product introduction process in order to minimize the risk of poor product maturity. Javadi, et al., (2016) concludes frequent disturbances are often a common result as products with poor manufacturability enter steady production. which according to Javadi, et al., (2016) can lead to frequent disturbances in the early production stages of volume production. This is a problem Javadi, et al., (2016) concludes as a result from the lack of opportunities to refine the product with a low number of production runs which leads to missing or incorrect information of the product.

When comparing the findings from the interviews with field notes from several observations in the production it also becomes apparent that the high production pace and the lack of time in the planning often results in that the securement of certain product criteria are not effectively communicated across the organization. Due to rescheduling in the work plan or various production disturbances, the start of a production for one product can easily be rescheduled for another time slot which could lead to that planned engineering activities and quality inspections becomes left out and thus affecting the securement of a product quality or work task standardization. This is a problem which has been confirmed by many of the persons in the interviews and seems to affect many of the main production departments. It is also reported through the interviews that the lack of product and process securement results in a poor manufacturability for certain products and high variation for certain processes and operations.

Table 18 - Problems connected to product

<table>
<thead>
<tr>
<th>Product</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product’s readiness for production</td>
<td>Account management, Engineering</td>
</tr>
<tr>
<td>Production disturbances</td>
<td>Planning</td>
</tr>
<tr>
<td>Production monitoring of products</td>
<td>Engineering, Production</td>
</tr>
<tr>
<td>Work instructions</td>
<td>Production</td>
</tr>
</tbody>
</table>

Production system

The account managers report that there exists a lack of internal measurements which complicates the account managers’ ability to follow-up on the programs’ performance. With no connection between the disturbances in the production and the performance of individual
customer programs it further complicates the company’s ability to perform continuous improvements of the production and to evaluate the costs tied to each customer program. As stated by account management, the lack of internal process measurements does impede the account managers’ ability to monitor the productivity and quality tied to each customer program at the company. With mixed customer processes the internal process measurements has to be managed on a holistic level to ensure that the production of products is measured in the same way.

In the production the prioritization is a daily struggle which is performed in collaboration with the planning department. With reoccurring disturbances and delays present in the production the decision of how the work orders should be prioritized becomes a problem. The daily production plan set by the production and the planners do ensure that the production produces according to demand, however, the constant changes of priorities and rescheduling can result in unforeseen disturbances and delays for products. From the findings in the interviews it becomes apparent that most pilot production are planned with highest focus and consideration for the SMT production. It does however seem that the planning of the rest of the production flow is not as detailed. If a non-communicated change of priorities is executed, it could lead to that the pilot production plan becomes affected.

The account management and engineering describes that a reoccurring problem is that many times the actual production performance is unknown for a product. The uncertainty of the actual production performance of a product is a problem which not only affects the product’s own production system but also the production as a whole.

The planning department reports that the unreliability of a products actual throughput-time affects the planning of work orders greatly. The unreliability in the SMT production itself is noted as what affect the total throughput time of a product the most. As the throughput time often is not verified for a product it further complicates the planning department’s ability to promise a certain order quantity to the customer. Actual throughput-time is also connected to the unreliability of the product’s manufacturability which also results from the company’s inability to secure the final production system.

As the production system is used “as is” in accordance with the characteristics as explained by Javadi, et al., (2016), with a mixed flow it becomes even more important that the project managers has the ability to measure the level of performance and product manufacturability in order to secure the final production system. The lack of resources and poor involvement of the production in the planning of new products hinders the coordination of the product introduction process as a whole which leads to that the process is only focused on the initial production processes. This characteristic is noted in the study by Javadi, et al., (2016) which leads to the inability to conduct an extensive production ramp-up process for the whole production. Unsecured production systems can not only result in poor manufacturability of the product, as stated by Surbier, et al., (2014), but also result in slow set-ups and unforeseen bottlenecks which can have further effects on the total production performance.

The lack of lead-time measurements on a new product combined with rescheduling of the production plan which affects the securement of engineering and quality activities can thus lead to a high uncertainty of the total lead-time of a new product. Not only does this result affect the promised delivery to the customer but because of the mixed production flow it will also affect the planning of other products throughout the production. This has been recognized as
one of the major problems for the planners at the company and has also been confirmed by the account managers as an on-going problem in the daily production.

Table 19 - Problems connected to production system

<table>
<thead>
<tr>
<th>Production system</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal process measurements</td>
<td>Account management</td>
</tr>
<tr>
<td>Prioritization of work orders</td>
<td>Production</td>
</tr>
<tr>
<td>Unknown actual production performance</td>
<td>Account management, Engineering</td>
</tr>
<tr>
<td>Variation in product through-put time</td>
<td>Planning</td>
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</tbody>
</table>

**Design-production interface**

For the purchasing department, the AML has been expressed as an important customer provided documentation which is needed in order to secure the material which is used for the production of the customer’s product. The AML is supposed to provide information about preferred material suppliers, material dimensions, packaging and other parameters which might be required as input in the production operations. As the AML is supposed to be provided by the customer for a new product in the start-up phase of a NPI project, the correctness of the AML is considered to be internally caused from projects. The ability to secure the information in the AML in an NPI is crucial in order to manage and secure the purchaser’s activities within the scope of the NPI project.

The product engineers reported that for many operations throughout the production, the uncertainty of when an operation is started or performed inhibits their ability to acquire first-hand information of the actual process operation. The product engineers therefore have to depend on acquiring the information from the operators working in the processes. Thus, with uncertainty of the reliability of the information received from a process it also complicates the engineer’s work with securement of the production processes and products. The ability to acquire first-hand information from a production run is a very important problem to consider in order to secure proper production of products. For new products this is even more important as most often the operators have never seen the product before and do not have the information of what technical aspects should be reviewed and evaluated when producing a product for the first time.

The inadequate material supply caused by material shortages and incorrect material balances in the material handling system is another problem which affects the flow of the production. Many of the disturbances and work order delays which affects the production processes are connected to the company’s material supply. Insufficient material supply and poor availability of material is a problem related to insufficient information when setting up the new supply chain as concluded by Surbier, et al., (2014).

The material information that is not covered by the customers’ AML is left to the case company to secure. In NPI projects it is very important that all material parameters are secured before the pilot production and that any feedback on the material used is provided to the purchaser before the project ending. The production and purchasing department confirmed that the securement of material parameters is a problem which occurs for many products. The purchasers depend on the product engineer to help them with this information before the first
material order, if no information is received for these parameters it is left to the purchasers to decide what to choose. Problems with the material parameters are therefore not corrected until the production provides feedback to the responsible purchaser.

The purchasing department described the ‘load & chase’-scenarios as a reoccurring event experienced when the customer product demand is suddenly increased resulting in an order increase which were not predicted by the customer forecast. The order and forecasting processes managed by the planners and account managers are supposed to regulate the expected product forecast and product orders in order to ensure that the material ordering process is able to keep up with the customer’s product demand. Although sudden order increases do affect material orders whenever a product are to be produced, the customer orders are always discussed and confirmed in the quotation process of a new product or in the customer order process which is managed by the planners. It is an unpredictable factor which affects the material supply.

For the engineering department much of the work tasks and activities depends heavily on the information and documentation of the customer. For the engineering processes which the customer documentation serves as an input to the process, the lack of standardization of customer documentation results in high variation of customer documentation formats which affects the outcome of the engineering processes notably. As seen from the NPI process model that the initiation of a project is determined by when the customer documents become available to the case company. However, the exist no criteria for what, where and how documents should become available to the company, thus making it hard to determine if the customer documentation and information actually sufficient enough to initiate a NPI project.

As Surbier, et al., (2014) notes in their study, an important factor of the design-production interface is to consider which information is necessary when setting up the logistics of the new supply chain. Communication and cooperation as described by Javadi, et al., (2016) is also an important part of the design-production interface which greatly affects the amount of opportunities to refine the product and productions system as the production runs are limited during the product introduction process. The ‘load & chase’-scenario is problem is located on the other end of the new supply chain where lack of information from the customer and the company’s unawareness of the customer’s ramp-up plan causes problem with the material availability of the end product to the customer as noted by Surbier, et al., (2014). The problem with securement of material parameters is also connected to the lack of information with the new supply chain which also causes disturbances with the material availability as stated by Surbier, et al., (2014).

It is discovered through many of the interviews that a department often has a need for certain information but has a difficult time and inability to acquire it. People absent from meetings and lack of informational sharing between the production and other departments is expressed as one problem which often leads to that some information which could have been of use to prevent early ramp-up disturbances or problems. This particular problem affects the engineering department which expresses that they often have to rely on second-hand information from the production. On the other hand, the product engineers also express that they because of lack of time many times does not have the time to attend to all meetings and activities which also results that they in turn does not receive feedback or general product information which could be of interest. The lack of first-hand information for the different
departments does not only affect the correctness and reliability of the information, but also the completeness of the information regarding products, processes and materials.
Table 20 - Problems connected to design-production interface

<table>
<thead>
<tr>
<th>Design-production interface</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctness of AML</td>
<td>Purchasing</td>
</tr>
<tr>
<td>First-hand information from production</td>
<td>Engineering</td>
</tr>
<tr>
<td>Material supply</td>
<td>Production, Purchasing</td>
</tr>
<tr>
<td>Securement of material parameters</td>
<td>Production, Purchasing</td>
</tr>
<tr>
<td>Sudden order increases</td>
<td>Purchasing</td>
</tr>
<tr>
<td>Variation of customer documents</td>
<td>Engineering</td>
</tr>
</tbody>
</table>

Quality

Risk and quality analyzes are reported to have a substantial effect of the end quality of products which are complex and unique for the company’s product portfolio. Even though certain analyzes are known to have an important effect on the performance of a product’s production, the analyzes are currently only performed on the initiation of the customer. As these analyzes are often related to expensive NRE costs, the cost incentive have limited the company’s requirements of performing internal risk and quality analyzes.

Inadequate material quality is reported as a problem which affects many processes throughout the production and the overall performance of the production flow. The production and engineering department report that material quality stands for many of the disturbances experienced in machine-operated processes. For production machines and processes which are very sensitive to the quality of the material, it becomes important that the used material meets the minimum quality requirement in order to ensure a smooth production.

The production, engineering and quality department that the follow-up on corrective actions for production problems is ever present when working in the production processes. Although many problems have been identified from previous work activities, it is described that these are rarely followed-up by management. Problem follow-up on corrective actions has been reported as a problem which the departments experience for both new and existing products. A lack of follow-up by the project manager on corrective actions in NPI projects do have substantial implications for the product’s readiness to enter volume production with the result of many non-conformities related to the quality of the end product.

The theories by Javadi, et al., (2016) and Surbier, et al., (2014) features sparse explanations of the aspects which causes the sources of disturbances related to quality. It can however be seen from the empirical results that the identified problems related to quality aspects of products and materials, that the causes can be traced back to how quality targets are assessed during the new product introduction process. Lack of internal risk and quality analyzes during the NPI process are said to have an effect of the quality of the end product of a ramp-up. Poor material quality results in quality problems in the process which is handled as either rework or scrapping as noted by Surbier, et al., (2014). Problem follow-up and the inability to incorporate corrective actions does lead to poor adaptation between the product and production system which also has been noted to result in quality issues at the start of volume production at the company which also is concluded by Javadi, et al., (2016).

It is confirmed by many of the interviewees from the listed departments in Table 21 that there are many identified issues related to the quality of materials and products. Even though the
main production departments are efficient in solving the problems connected to a product’s quality when discovered, the pilot production is rarely used for securing both material and product quality to the extent that they can ensure a satisfactory product maturity and readiness for volume production.

Table 21 - Problems connected to quality

<table>
<thead>
<tr>
<th>Quality</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal risk and quality analyses</td>
<td>Quality</td>
</tr>
<tr>
<td>Material quality</td>
<td>Production, Engineering</td>
</tr>
<tr>
<td>Problem follow-up</td>
<td>Engineering, Production, Quality</td>
</tr>
</tbody>
</table>

Resource management

The high workload is confirmed by many departments at the company which affects several processes and activities. It is however the engineering department which is reported as one department which is affected the most by this problem and it has several implications for other department processes and the performance of engineering tasks. The overall workload at the company is explained as problem which affects many departments’ ability to perform and secure the process activities for programs and projects. Most concerned about the high workload is the product engineers, which explain that the workload balance caused by their involvement with many customers for both project and program activities affects the daily engineering work substantially.

The production reports that the resource capacity often becomes a problem when planning the daily resource distribution in the processes. Machines are reported as a bottleneck itself but for some processes the occurrence of single-sourcing among employees also becomes a bottleneck for the production’s resource capacity. As explained by the production manager in the interview, management of the company’s production resource capacity is handled separately from the introduction of new products. The production uses existing machine processes for the customer products with the exception of test equipment which are often product unique. Any process bottleneck therefore becomes an external factor which has to be regarded in every NPI project.

The resource planning is based on the monthly forecast of the customers’ resource demand and the daily planning meetings. To ensure a sufficient resource capacity, the difference of the resource demand forecast and the confirmed work orders must be kept as low as possible. As some work orders can take several days to complete, it is important that any confirmed changes to resource demand of a program is communicated to the production upon notice. Resource planning is a problem which is not currently considered in NPI projects.

As noted by Javadi, et al., (2016), the dual involvement in product introduction projects and on-going production limits the ability of proper resource management. As seen from the empirical results this is also the case at the company in research which results in that the engineering department experiences a high workload. Surbier, et al., (2014) notes that many times the methods for piloting a ramp-up are often not adapted for the characteristics of a ramp-up process. Regarding resource management for pilot productions, the planning of resources is handled in the same manner as the production is planned for mature products.
and steady production which leads to that the experienced capacity and resource availability during pilots is constrained.

An experienced high workload for both the production and engineering department is also linked to the formerly listed problems. Lack of time to secure production activities combined with work rotation which affects single-source competence leads to that the status and verification of certain process steps can be unreliable due to lack of follow-up or inexperience from the operators.

Table 22 - Problems connected to resource management

<table>
<thead>
<tr>
<th>Resource management</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>High workload</td>
<td>Engineering</td>
</tr>
<tr>
<td>Resource capacity</td>
<td>Production</td>
</tr>
<tr>
<td>Resource planning</td>
<td>Production</td>
</tr>
</tbody>
</table>

Personnel

A combination of old and sensitive machinery results in a noted unreliability of the output of some processes. For the process engineers this can complicate the ability to secure proper process performance and a reliable production output. It also puts an emphasis on the level of knowledge and qualification of the operators handling the machinery as the operators has to learn how the machinery performs under certain conditions.

As concluded by Javadi, et al., (2016), a critical role during the product introduction process is the learning and training of the production personnel. As the production system at the company is often used ‘as is’ for many production flows it becomes important that the dynamics of old machinery is considered by the project managers during the planning of a new product. For processes where machinery is known to have considerable variation of performance it becomes critical that the operators and process engineers is given the time to learn how the product behaves in the existing production system.

Table 23 - Problems connected to personnel

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unreliable machinery</td>
<td>Engineering</td>
</tr>
</tbody>
</table>
5.2 Factors which Influences the Performance of NPI Projects

The next step in the analysis is to find a possible linkage of the identified problems which are connected to the output of the NPI projects to the project factors which have been identified from the interviews. As many of the factors and shortcomings might be interconnected internally in a project, the results from the different departments has to be compared with the theories presented in the analytical model in order to find out which true factors that actually acts as a root cause to the identified production problems.

Product

The decision of when maturity of a new product is sufficient for a volume production is determined by the engineering department and the project managers depending on the outcome from the pilot production. At the start of a project or even in the project negotiation with the customer product complexity and uniqueness of the product in the existing production system has to be considered and how it will affect the project scope. Also, as most NPI projects which are performed at the case company only feature a single pilot production run the amount of verification of the ramp-up volume might not be sufficient to ensure that the productivity and quality targets in a NPI project has been met. If product complexity is very high a pre-series might have to be considered as a requirement to ensure that the existing production environment is not affected by the new product. Design reviews as stated by Adler (1995) is an important part of securing the requirements of a new product. By implementing them early in the process and continuously throughout the process will facilitate the process of finalizing the end product.

The production disturbances are a negative loop which not only is a common situation in ramp-up processes, if not effectively identified and rectified during the product introduction process the remaining sources of disturbances will affect the introduction of new products as well as the steady production of other products. The results from the study by Li, et al., (2014) shows that the use of a systematic ramp-up process is necessary for early disturbance identification and rectification with clear fallback loops which ensures that disturbances are limited from reaching the start of steady production.

The lack of monitoring of new products in the production by the product engineers was confirmed by both the production department and the process engineers. The product engineers explain that they are aware of that the monitoring of products are lacking. Another factor which is said to complicate the ability to monitor the product flow in the production is the mixed product processes and a lack of involvement with the planning for the pilot productions. However, it is explained that the support of monitoring from the production itself is their biggest concern. The product engineers report that they have to rely on the production operators and coordinators to notify them when the pilot production operation is started. This is a very unreliable process and many times it often results in that the product has already gone through a process in the production when the product engineers are supposed to monitor the product process. As Ruffles (2000) also concludes in his study, an important factor is to involve the production early in the product introduction process. Furthermore, as Almgren (2000) concludes in his study it is also necessary that the pilot production is supported by the production organization to effectively identify sources of disturbances which might affect the final performance of the product as early as possible.
The status and performance of work instructions for new products and production systems are not only affected by the completeness of the customer documentation but also the feedback from the performance of the pilot production. As explained by Surbier, et al., (2009) it is important that the interface and information regarding maturity of information and proper communication channels is considered in the planning of a ramp-up project in order to ensure sufficient flow of information at the beginning and throughout the product introduction process.

Table 24 - Factors connected to product

<table>
<thead>
<tr>
<th>Product</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product’s readiness for production</strong></td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Follow up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Product complexity,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production performance.</td>
</tr>
<tr>
<td><strong>Production disturbances</strong></td>
<td>Mixed product processes,</td>
</tr>
<tr>
<td></td>
<td>Standardization of work procedures.</td>
</tr>
<tr>
<td><strong>Production monitoring of products</strong></td>
<td>Cross-functional planning,</td>
</tr>
<tr>
<td></td>
<td>Mixed product processes,</td>
</tr>
<tr>
<td></td>
<td>Roles and responsibilities.</td>
</tr>
<tr>
<td><strong>Work instructions</strong></td>
<td>Cross-functional production planning,</td>
</tr>
<tr>
<td></td>
<td>Extent and readiness of customer documentation,</td>
</tr>
<tr>
<td></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Product complexity,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production performance.</td>
</tr>
</tbody>
</table>

Production system

The lack of internal process measurements is described as a problem for the account managers to evaluate and assess the performance of products and programs. In order to achieve the third ramp-up goal ‘Strengthening of resources for high quality’ as described by Winkler, et al., (2007), it is necessary that the production processes reach a minimum level of quality in regards to the level of performance of machinery, raw material and work force. Fjällström, et al., (2009) also concludes that when handling problem events related to product introduction process it is necessary to acquire as much information as possible as much of the caused disturbances are interrelated with each other.

As confirmed by the production, planning and purchasing department the inadequate material supply is the biggest concern for the availability of material in production. However, the product engineer in one of the interview reported that for many pilot production, the cause of many delays were related to tight material deliveries. As seen from the NPI project model the delivery of project material is supposed to be secured before the start of the pilot production. The findings would suggest that the planning of the pilot production is set before the confirmation of the material delivery date in a projects which would result in that the planning might affected by late deliveries. The production plan is heavily dependent on that the material supply is sufficient at the start of a work order. Strengthening of resources for high productivity is the first ramp-up goals as described by Winkler, et al., (2007). For new products this has to be
especially considered and productivity targets has to be set for the new product to ensure that material is used in a pilot production is coordinated as it would be if the product was being produced in volume production. Inadequate material supply also limits the productions ability to realize products as planned, which according to Winkler, et al., (2007) is the second goal of the ramp-up process. Almgren (2000) also identified in his study how poor verification of disturbances in the pilot production can lead to problems with the material availability which ultimately affects the final performance and output.

As most of the focus for the production planning is focused on the SMT production it is explained that it affects the prioritization of the following operations in the production flow. The mixed product processes are also something which affects the prioritization between pilot and volume production. As program management is often prioritized over projects it could lead to a negative effect on the pilot production planning with delays that further affect the ability to secure the end result of a new product. The systematic ramp-up process suggested by Li, et al., (2014), also addresses the standardization of the ramp-up process in order to enable priority of focus while still maintaining a an efficient and capable process which can be managed according to the initial plan of the project.

The mixed product processes do put a high pressure on the planning of the production, where every product or process related disruption can lead to long delays and rescheduling of the original production plan. As reported by one of the account managers there is also a lack of standardization for the project managers work procedures which results in that the performance of a NPI project is connected to the individual performance and commitment of the project managers. In order to ensure that the outcome and output of each project can be predicted, the variation of how projects are performed has to minimized. As the production feature a high mix of product processes, it further complicates the ability to determine how the project output will affect the already existing production system. This problem is also related to the lack of a systemized and standardized process as described by Li, et al., (2014). In order to improve the predictability of the production yields and the accuracy of production planning, the ramp-up process planning must not only be shared on internal level in the company but also within the supplier network for the company.

Securing the actual production process performance is one of the goals with conducting a pilot production in NPI projects. It is also connected to the ramp-up goal of strengthening resources for high productivity (Winkler, et al., 2007), and is an important process in order to ensure that the production of a product turns out according to what has been planned and to ensure that the financials of a product series production will result in profit for the customer program. Almgren (2000) also notes the importance of testing the production system as close to full steady production conditions as possible with focus on final verification of the process. Chwastyk & Kolosowski (2014) also noted the importance of correcting deviations related to the process in order to verify the financial result of project.

The same ramp-up goal (Winkler, et al., 2007) concerns the problem with the variation in product through-put time as experienced by the planners. Time studies for new products can be an efficient tool in order to measure and compare the planned production with the actual production of a pilot product to ensure that the product through-put time is not based on a best case production scenario where production disruptions and defects are excluded.
Table 25 - Factors connected to production system

<table>
<thead>
<tr>
<th>Production system</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal process measurements</strong></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Priority of quality focus on processes,</td>
</tr>
<tr>
<td></td>
<td>Product quality specifications from customer.</td>
</tr>
<tr>
<td><strong>Material supply</strong></td>
<td>Cross-functional production planning,</td>
</tr>
<tr>
<td></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Mixed product processes.</td>
</tr>
<tr>
<td><strong>Prioritization of work orders</strong></td>
<td>Cross-functional production planning,</td>
</tr>
<tr>
<td></td>
<td>Mixed product processes,</td>
</tr>
<tr>
<td></td>
<td>Priority of quality focus on processes,</td>
</tr>
<tr>
<td></td>
<td>Project priority.</td>
</tr>
<tr>
<td><strong>Unknown actual production performance</strong></td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Linkage between quality targets in projects and production,</td>
</tr>
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<td></td>
<td>Project closure,</td>
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<tr>
<td></td>
<td>Roles and responsibilities,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production performance.</td>
</tr>
<tr>
<td><strong>Variation in product through-put time</strong></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Mixed product processes,</td>
</tr>
<tr>
<td></td>
<td>Priority of quality focus on processes,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production performance.</td>
</tr>
</tbody>
</table>

**Design-Production Interface**

As with customer documentation the correctness of an AML can vary between projects and customers. It is therefore important that the project managers are well informed of what information the purchasers require to eliminate unnecessary project work where the purchasers have to spend time in order to acquire the correct information from the customer. If the customer cannot provide sufficient information at the start of a project, it is important that the project managers evaluates how the correctness of the AML will affect the securement of the product material and possible deviations of the project timeline. In short, a trade-off between customer flexibility and internal process requirements has to be made in order to ensure that the company can provide a sufficient service level towards the customer without risking the internal process requirements. Informational requirements as explained Surbier, et al., (2009) is critical in the initiation of a project in order to secure the correctness and maturity of the information provided for planning and set-up of the new supply chain.

From the interviews with the operation coordinators and the product engineers it becomes apparent that the perception of who is actually responsible to report on the pilot production’s performance is not clear. The operation coordinators and operators in production is of the expectation that the product engineers are supposed to be physically available in the production whenever a pilot production operation is started. The product engineers on the other hand rely on the operators to report about how the pilot production were performed and call for their attention is a problem with the product occurs. It is also reported that the difference
between the current projects managers and the former dedicated project managers had a different commitment to follow-up on the information from the production. Another implication to the ability for the product engineers to acquire first-hand information is the lack of cross-functional production planning with the planners for the pilot production and the lack of detailed planning for the whole pilot production flow. As explained by Bauer, et al., (2014) it is important that the project manager of a ramp-up is aware of the organizational interface and the clarity of roles and responsibilities in order to identify disruptions proactively and ensure short reaction times on failures.

As stated in the interview with the purchaser the amount of new material for a product can have a substantial effect on the workload with securing material parameters in a NPI project. It is also important that the purchasers know what parameters are critical depending on which type of components and material is to be secured. Furthermore, the purchaser reports that the product engineer does have the knowledge required to help them secure which parameters should be used depending on which operation the product engineer has planned for the new product. However, there does not currently exist any routine in a project where the purchasers and product engineers goes through the new material in order to secure the final material information before the project is ended. With the lack of verification and feedback from the pilot production run it further complicates the purchaser’s ability to secure proper material information before the projects are ended. The capability of a rapid ramp-up process, as described by Li, et al., (2014), is dependent on mutual awareness of the ramp-up plan in the supplier network. For contract manufacturers which is often a part of a multi-connected supply chain network it is important that the planning of new materials is initiated as early as possible in the product introduction process.

The sudden order increases were described as a scenario which were experienced to have a long-term effect on the production as it affects the planning of other products in the mixed product processes. However, it is partly related to the company’s high flexibility towards customer which also affects the company’s own performance. As order increases are more often accepted as a rule than an exception by the contract manufacturer it becomes important that the planning of orders is communicated with the production as whole and that the limitation of mixed product processes will create situations were a rise in demand from customer will affect the order planning and delivery performance of another. Fjällström, et al., (2009), identified the supplier information as a critical factor where availability of materials is a common type of information. As a contract manufacturer, acting a supplier in turn for the customer, is critical that the enablement of such information is coordinated internally as well as externally with the stakeholders in the supply chain.

As with the AML, the project managers also have to be aware of how the readiness and extent of the customer documentation might affect the project work for the engineering department. The NPI projects at the case company are currently initiated as soon as the customer documentation becomes available from the customer. A benefit to the NPI process would be that project are initiated as soon as the customer documents has reached the requirements of the case company as a decrease of variation in customer documentation will have a minimized effect on the planned timeline and workload for the NPI projects.
Table 26 - Factors connected to design-production interface

<table>
<thead>
<tr>
<th>Design-production interface</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctness of AML</td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Customer flexibility,</td>
</tr>
<tr>
<td></td>
<td>Extent and readiness of customer documentation.</td>
</tr>
<tr>
<td>First-hand information from production</td>
<td>Cross-functional production planning,</td>
</tr>
<tr>
<td></td>
<td>Project manager commitment,</td>
</tr>
<tr>
<td></td>
<td>Resource allocation,</td>
</tr>
<tr>
<td></td>
<td>Roles and responsibilities,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production flow,</td>
</tr>
<tr>
<td>Securement of material parameters</td>
<td>Amount of new material for product,</td>
</tr>
<tr>
<td></td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Follow-up on product’s ramp-up quality,</td>
</tr>
<tr>
<td></td>
<td>Material samples,</td>
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<tr>
<td></td>
<td>Project meetings,</td>
</tr>
<tr>
<td></td>
<td>Verification of actual production flow,</td>
</tr>
<tr>
<td>Sudden order increases</td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Cross-functional production planning,</td>
</tr>
<tr>
<td></td>
<td>Customer flexibility,</td>
</tr>
<tr>
<td>Variation of customer documents</td>
<td>Awareness of internal process requirements,</td>
</tr>
<tr>
<td></td>
<td>Customer flexibility,</td>
</tr>
<tr>
<td></td>
<td>Extent and readiness of customer documentation,</td>
</tr>
<tr>
<td></td>
<td>Project initiation</td>
</tr>
</tbody>
</table>

Quality

The biggest discovery from the interviews was that the quality department currently has no involvement in the NPI projects performed at the case company. Not only does this result that the quality assurance of new products is affected, it also means that the quality targets for a new product are currently not linked to how the quality department manages the quality of existing products in the production. The quality engineer further explained that the case company does not support the performance of internal risk and quality analyzes, even though it has been reported that these analyzes do have a positive effect on the performance on complex products. High customer flexibility and the difference in organizational project culture further polarizes how project managers execute projects at the company. As mentioned by Winkler, et al., (2007), the usage of risk assessment tools, such as FMEA, are important for the project managers to be able to foresee possible disruption outcomes to ramp-up projects. As described by Winkler, et al., (2007), one of the responsibilities of the project manager is to minimize and eliminate any disruptions to a ramp-up project. Even though the customer is not interested in paying for certain project analyzes, the project managers has to determine what the minimal requirements are for managing project risks and quality based on the scope of the project and thus be able to perform internal analyzes if necessary.
The operation coordinator reports that material samples are a factor which affects the production operators’ ability to secure the quality of material. As material samples often are provided in different packaging and often not prepared correctly for the operation, it cannot be known how the quality of the material ordered for volume production will turn out. The quality engineer also reports that the ramp-up volume is a factor which affects the ability to secure the quality of the material ordered. As the pilot production volumes are often rather low, the sampling of material used for the production is often too low in order to identify quality defects of bigger material batches and follow-up on possible material quality defects. Strengthening resources for high quality is also part of the ramp-up goals as described by Winkler, et al., (2007). Not only is this activity important for the purchasers but also the engineering department which has to oversee that the new material ordered for a new product is of sufficient quality to ensure that the process will work accordingly to what is planned for the new product.

In the findings from the interview it was reported that the focus of securing productivity and quality is often focused entirely on the SMT production rather than for the whole production flow. The quality engineer also states that the follow-up on corrective actions is non-existent at the company which together with a unilateral focus on the production processes leads to that the ramp-up quality of new products cannot be guaranteed. Early project closures, lack of summary meetings and passive project managers do show that the NPI projects lack a sufficient final phase. The project managers on the other hand explains that the cause of their lack of commitment is caused by the dual role of involvement with project and program management, requiring them to rely on autonomy and self-responsibility of the project team members during the project course. The lack of proper project endings and securement of product’s ramp-up quality is an implication that can have negative effect for the whole company ultimately. Although it was not identified how the shifted focused of securing productivity and quality for only a part of the process affects the process and program performance as a whole, it can be noted from the featured studies from related research such as Chwastyk & Kolosowski (2014) that the lack of final verification of the process has implications for the final products manufacturability, quality and cost.

Table 27 - Factors connected to quality

<table>
<thead>
<tr>
<th>Quality</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal risk and quality analyses</td>
<td>Awareness of internal process requirements, Customer flexibility, Linkage between quality targets in projects and production, Organizational project culture, Product quality specifications from customer, Product complexity, Project involvement, Project risk management.</td>
</tr>
<tr>
<td>Material quality</td>
<td>Amount of new material for product, Follow-up on product’s ramp-up quality, Material samples, Ramp-up volume.</td>
</tr>
<tr>
<td>Problem follow-up</td>
<td>Follow-up on product’s ramp-up quality, Priority of quality focus on processes,</td>
</tr>
</tbody>
</table>
Resource management

The high workload expressed by the product engineers is connected to the resource allocation and responsibility in the organization. As the engineers often have to support the production with urgent problems it does lead to inefficient project work and the possibility that somethings are overseen and missed. The lack of resource allocation does effect new projects executed at the case company as the product engineers are often assigned to several customers and projects. There is also the implication with the organizational project culture, as reported by one of the account managers, most projects performed at the company is often considered as supportive service and more priority is given to the program management. The high workload is connected to the characteristic of low-volume production (Javadi, et al., 2016), it is however not clear with the featured research from the other studies how it is connected to common factors in a ramp-up as many of the studies are based on production in high-volume manufacturing with isolated production systems. The lack of proper resource allocation for projects at the case company does however explain that it becomes unknown to the project managers of the resource availability in NPI projects.

The constrained resource capacity and the situation of single-sourcing for certain process operations is explained as a problem for the volume production which is caused by the lack of involvement and communication of daily production planning and planning of resources in ramp-up project in the NPI process. As the planning of resources and work orders are disconnected it does affect which resources that are involved in the pilot production of new products. For the SMT production it is often important that the regular operators and process engineers are involved when a pilot production is started, this is however not how the resource planning is performed for the rest of the production flow. As reported from the operation coordinator in the HMT, the information of when a pilot production is to be started can often be provided too late which can lead to that the resources which were intended for use in the pilot production are currently unavailable. It is thus important that the resource planning for pilot productions are taken into consideration when performing the planning the pilot production of a new product. As explained by Winkler, et al., (2007) learning and work force training is an important factor in ramp-ups and it also means the managers has to take careful consideration when planning the production resources for pilot production. In accordance with Ruffles (2000) it also dependent on how the production is involved in the product introduction process and the general involvement of all disciplines which are associated with the design, manufacturing and support of the product.

Table 28 - Factors connected to resource management

<table>
<thead>
<tr>
<th>Resource management</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>High workload</td>
<td>Organizational project culture, Resource allocation, Roles and responsibilities.</td>
</tr>
<tr>
<td>Resource capacity</td>
<td>Cross-functional production planning,</td>
</tr>
</tbody>
</table>
Project involvement, Resource allocation, Verification of actual production performance.

| Resource planning | Cross-functional production planning, Priority of quality focus on processes, Project involvement. |

**Personnel**

As a contract manufacturer which uses a single flexible production system which produces products from multiple customers in the same machine processes it can rarely be considered to invest in new machinery during the introduction of a new product from one customer. It does however put more emphasis on how the company considers the product-process fit and the introduction of a product with high novelty or complexity. The process engineers mention that it is difficult to secure the processes because of the machinery. At the same time, the empirical findings from the interviews with quality showed that the follow-up on quality issues has provided findings which suggests that identified disturbances during the NPI process are rarely rectified which results in a poor output from the process. Both Adler (1995) and Apilo (2003) suggests that extensive design reviews is necessary in order to follow-up on ramp-up quality. Almgren (2000) also concludes that a lack of verification of identified disturbances leads to problems such as machine downtime, quality losses and reduced manufacturing speed which suggests that the unreliability of the machinery could be improved with better follow-up and verification of the machine processes during the pilot production.

Table 29 - Factors connected to production system monitoring

<table>
<thead>
<tr>
<th>Production system monitoring</th>
<th>Project factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unreliable machinery</td>
<td>Follow-up on product's ramp-up quality, Priority of quality focus on processes, Product complexity, Verification of actual production performance.</td>
</tr>
</tbody>
</table>
6 CONCLUSION

This chapter answers the research questions of the study and presents its theoretical contribution to the subject of research.

6.1 ANSWERS TO RESEARCH QUESTIONS

RQ1. What are the most common problems experienced for volume production of products which are connected to the output of the product introduction process?

The study identified several reoccurring problems from the main production departments at the company, which were interconnected and confirmed by more than one department. The problems both did not only affect the production of products but also the work of other departments.

The identified problems can be summarized into the following problems regarding the volume production of products:

- Problems with manufacturability of products,
- High variation of process performance,
- Poor correctness on information,
- Quality issues with products,
- High workload on resources.

Poor securement of certain product criteria is said to be a problem which influences the manufacturability of products at the company and results in a high variation for certain processes and operations.

Lack of first-hand information, incompleteness in customer documentation and lack of feedback in meetings also results in the problem of poor correctness of the internal production information regarding products, processes and materials.

It is confirmed by many of the interviewees from the Production, Engineering and Quality departments that there are many identified issues related to the quality of materials and products. Even though the main production departments are efficient in solving the problems connected to a product’s quality when discovered, the pilot production is rarely used for securing both material and product quality to the extent that they can ensure a satisfactory product maturity and readiness for volume production.

An experienced high workload for both the production and engineering department is also linked to the formerly listed problems. Lack of time to secure production activities combined with work rotation which affects single-source competence leads to that the status and verification of certain process steps can be unreliable due to lack of follow-up or inexperience from the operators.
**RQ2. How do the identified factors influence the performance of the product introduction process?**

Many of the problems which were identified as being affected by the ramp-up project output for executed NPI project at the company were linked to several factors which the project team experienced during the course of the ramp-up project.

In accordance with the studies by Fjällström, et al., (2009) and Surbier, et al., (2009) the information interface and communication at the company is connected to several of the problems experienced in the volume production. The handover of customer documents is one of the factors which affects the initial phase of the product introduction process and because of a lack of internal process requirements of what is considered as mature information, the variation of customer documentation has an effect on the how the projects are executed according to the ramp-up planning.

The case company featured little or no involvement with the production and quality department which are associated with the manufacturing and support of products during the product introduction process, which results in the uncertainty of verifying the end product of the ramp-up process in terms of manufacturability, quality, and cost.

The lack of organizational project culture has not been identified from other ramp-up studies in the literature review as a factor which affects the ramp-up performance. However, it is identified as a characteristic for low-volume production manufacturing (Javadi, et al., 2016) and contract manufacturers (Kontio & Haapasalo, 2005) were companies operate in non-continuous manufacturing with alternating project-production modes.

Another factor which has not been identified by other ramp-up studies but has been confirmed by many interviewees is customer flexibility. The company’s high flexibility towards the customer is confirmed to influence the NPI process in the aspects of the product maturity and quality securement during pilot production, affecting both the completeness of customer documentation and the product’s readiness for volume production.

The findings of the identified problems and factors, which were linked together, showed that the case company’s ramp-up projects experienced many shortcomings which had a direct implication and effect for the performance of the volume production of new products. A summary of all the linked production problems and project factors is given in the table below.

### 6.2 Contribution of the Study

The theoretical contribution of the study is seen from the identification of commonly experienced problems in the volume production in the electronics industry of a contract manufacturer and how these problems are connected to the project management and identified factors in the ramp-up project executed at the contract manufacturer. The linked problems and factors to ramp-up project and processes experienced for a contract manufacturing company may differ from the other companies in the same industry which produces their own products. However, the outcome of the study may be of use for other companies in the same industry to understand how the introduction of new products to the existing production flow can affect the production system and business processes for departments which are involved with the manufacturing of products at the company.
7 REFERENCES


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8 APPENDICES

8.1 ELECTRONIC PRODUCTS & COMPONENTS

The technology in the electronics industry is moving forward in a very high pace (Coombs, 1996). Moore’s law regarding integrated circuit (IC) sizing stays true in the electronics industry where R&D in the semiconductor industry pushes component sizing for new technological breakthroughs each decade where electronics has gone from stationary and cabled to mobile products with wireless communications (Moore, 1965; Coombs, 1996; Strawn & Strawn, 2015). The impact of this puts pressure on electronics manufacturers of electronic assemblies to reduce the physical design and packaging format for the end product (Coombs, 1996).

8.1.1 PRINTED CIRCUIT BOARDS

All electronic components must be interconnected and assembled in order to form a functional and operating system. The most common basis for any electronic circuit and modern electronic products today is the printed circuit board (PCB). PCBs are used to provide a mechanical basis on which the electronic circuit can be built upon with the fundamental structure of interconnecting mounted components through electrical conductor paths. The majority of PCBs produced today are graphically produced boards, meaning that the circuit pattern on the board is formed photographically on a photosensitive material (Coombs, 1996). There are three types of graphically produced boards:

1. Single-sided boards
2. Double-sided boards
3. Multilayer boards

The single-sided boards have circuitry on only one side meaning that the components can only be interconnected and mounted on one side of the board. Double-sided boards have circuitry on both sides. Moreover, the circuitry can be connected with plated through-holes so that a component on one side is connected to a component on the circuit on the opposing side of the board. Multilayer boards (MLBs) consist of three or more circuit layers. The inner circuit layers are connected to each other and the outer layers are connected through plated through-holes or vias. Vias occupies less space on the board which in turn reduces the need of through-hole plating effectively reducing the size of the board and costly processing steps of board drilling. This enables the components to be packed even tighter on the board. This advantage has made MLBs the mainstream solution for modern electronics devices and consumer products such as portable video cameras, mobile phones and computers (Coombs, 1996).

8.1.2 ASSEMBLED COMPONENT TYPES

A wide range of methods has evolved for attaching components to PCBs and the methods chosen have substantial impact for the products final cost, ease of assembly, availability of components, ease of test and ease of rework. Many producers of electronic products also have some type of machinery or robotic assembly which automates the process steps of assembling components with these attachment methods resulting in increased production volume, lower cost and minimal human error (Coombs, 1996). The most common forms of attachment methods are:

- Through-Hole Only,
- Through-Hole Mixed with Surface-mount,
- Surface-mount, One Side Only,
- Surface-mount, Both Sides,
- Surface-mount, Both Sides with Through-Hole.

Through-hole components are characterized by parts which have wire or formed leads. These leads or wires are fed through the plated through-holes and soldered on the opposing side onto the circuitry to create the conductive interconnection. The main characteristic of a surface-mounted component on the other hand is that the leads are much smaller. The connection is thus made with pads located on the surface on the PCB instead. Another characteristic, and benefit, of surfaced mounted components is that they are always smaller than their through-hole equivalent, enabling a higher density of components in a given area (Coombs, 1996). The mechanical design for one component type each method varies greatly depending on their supplier. Height, width, length of leads, form, and color, can have huge impact for the design of an electronic circuit and its assembly. The packaging from the supplier can also be very different and serves many purposes. Spools, trays, strips, or bulks of components is a choice for purchasers which carries great impact on the fabrication depending on in which process of assembly the components are used (Coombs, 1996).

8.2 Printed Circuit Assembling in Electronic Manufacturing

Printed circuit boards and automated electronics assembly has developed significantly over the past decades. New applications keep pushing the limit for smaller form factor with increased performance. In the electronics market, which is characterized by shorter development cycles, intense global competition, and rapidly evolving technology, understanding the assembly equipment and processes is necessary in order to ensure the companies place on the market. PCB manufacturing is a very complex business in itself with several processing steps. Therefore, for many contract manufacturers this process is commonly outsourced to specialized suppliers of PCBs and the finished product is purchased ready for assembling from the sub-supplier (Coombs, 1996).

Electronics assemblies can according to Coombs (1996) be grouped into three categories:

- Through-hole assembling
- Surface-mount assembling
- Mixed-technology

Through-hole assembly has been the most common assembly method for electronics manufacturing over the years and new machinery is still being developed and introduced on the market. However, for modern electronics products and consumer devices surface-mount assembly has become the new production champion where new sophisticated machinery has streamlined the manufacturing layout with fully automated production chains. Although promising, the reality for PCB assembly process is still getting more complex and challenging to manage. Globalization of supply chains is driving the need for multilingual applications. Odd-form components are being automated to keep up with the line throughput and takt-times. Alternative component attachment methods are growing at a faster rate and to complicate the process even further, several applications require mixed technologies, which put a greater burden on equipment manufacturers (Coombs, 1996).
8.2.1 Through-Hole Assembling

The use of through-hole assembling and components can be the most cost-effective for a product. The through-hole production requires less material costs, production engineering costs and assembly costs compared to the assembly process of surface-mount technology (Coombs, 1996). The automatic assembly of through-hole components almost always follows the same sequence of events for which the sequence follows this order:

1. DIP insertion
2. Axial leaded assembly
3. Radial leaded assembly
4. Odd-form components

DIP or dual-inline components mostly regard IC-components. The components come packaged in plastic tubes which are fed vertically in magazines which are carried to the center of the assembly machine where it is inserted automatically onto the board. The second insertion process is the assembly of axial leaded components. These components come packaged with their leads taped by their ends onto spools. The machine cuts, forms and inserts the components in a sequential order depending on size and placement. As axial components are smaller in overall size, this assembly process is done prior to the insertion of radial components. Radial components can vary greatly in size, shape, height, and weight. Packaged in the same manner as axial components these components are cut and inserted with a gantry-style tool system with tools for each component design. The term of odd-form components is often used to describe components which cannot be inserted by the previously mentioned through-hole processes. They may include DIPs, axial or radial if the volume is too low to justify the setup of automatic insertion of the components but can also include components such as displays, buttons, connectors, and cabling. Most often, these components are inserted manually onto the board although some insertion of odd-form components may be automated through special fixtures (Coombs, 1996).

8.2.2 Surface-Mount Technology

Surface-mount technology (SMT) regards several process steps for surface-mounted components. As modern electrical products and consumer devices can include several hundreds of surface-mounted components the related process are often automated through robotic or highly advanced manufacturing equipment. These automated processes can involve process steps such as solder paste dispensing, component assembling, soldering and even inspection. Although the costs for SMT processes regarding engineering labor, machinery, and components prices are often very expensive compared to their through-hole equivalent, the increase in throughput-time and production volumes is unmatched (Coombs, 1996).

8.2.2.1 Line Assembly and Set-up

Surface-mount technology enables assembling of component on both sides of a PCB. The SMT-lines are most often modular with different types of dispensers, curing ovens, and component placement modules, effectively enabling the line to be set up to handle a certain fixed range of component and board sizes, which provides great flexibility to the manufacturer. Most often, the assembly process starts with placement of components on the top-side first followed by the bottom-side placement. The process for each side starts off with dispensing of adhesives or solder paste. Components are then placed onto the board in a placement machine(s). Finally, at the end of the process, the board passes a curing or reflow soldering
oven before the board is moved onto the next process. The typical SMT assembling process can be summarized as follows for top-side and bottom-side respectively (Coombs, 1996).

There are two general line architectures for the conventional SMT line (Coombs, 1996) as illustrated below:

1. Traditional bottom-side line

2. Bottom-side line with solder paste application

As seen from the pictures above, the main difference between these two line set-ups are the dispensing application for adhering the components to the board.

For the traditional bottom-side lines, the process starts with the assembling of the top-side. Once the top-side is finished and the board has been flipped, adhesives are applied to certain locations on the bottom-side which is later cured in an oven. When the bottom-side is finished,
the board is flipped once more and passes through a wave solder process, which solders the bottom-side surface-mounted components and any through-hole components in place. The adhesive dispensing setup is followed by a curing oven which strengthens the bond between board-component so it can be soldered in a following wave-solder process (Coombs, 1996).

The other bottom-side line process with solder paste application, however, often uses a two-sided reflow process which uses solder paste with different curing temperature on each side of the board to secure the placements of components. This process eliminates the need for different top- and bottom-side configurations and also the need for traditional adhesives and following wave-soldering processes (Coombs, 1996).

8.2.2.2 Adhesive Dispensing

As surface-mounted components, unlike through-hole mounted, are not inserted into the board the leads are not clinching to hold the components in place. The use of adhesives or solder paste ensures that the placed components stay put on the board through the whole assembling process. Adhesives such as epoxies, silicones and other adhesives which are cured for securement has been used traditionally to adhere components in SMT assembling. However, the use of solder paste has replaced the former traditional adhesive materials as the process involves fewer processing steps. Solder paste is an adhesive which both adheres components and creates solder joints through the use of a reflow soldering oven, thus eliminating the process of wave-soldering (Coombs, 1996). There are several dispensing techniques for applying adhesive onto a board, which each have their advantages and disadvantages. This thesis will describe one of them which applies to the case company, namely screen or stencil printing.

Screen or stencil printing is a dispensing technique with the major advantage of applying solder paste over the whole board at once. A stencil/screen plate with apertures for each component and solder pad is placed flat onto the board. A squeegee passes over the plate and forces the solder paste into each opening and onto the circuit. Although the technique is very volume and time efficient, there are some implications with this method. One of them is that the stencil must be kept clean between each setup to allow the adhesive dots to form properly. Cost is another implication, as a new stencil is required for each product (Coombs, 1996).

8.2.2.3 Component Placement

There are two common types of placements machines which can be found for surface-mounted components. The first one is the turret-style chip-shooter and the other is the gantry-style flexible fine-pitch machines, also called pick-and-place. In a chip-shooter placement machine, the components are moved through a feeder carriage into the chip-shooter which detects its presence, rotates the component if necessary and "shoots" the component into position onto the board. The chip-shooter has multiple heads for different sizes and shapes of components.

The pick-and-place placement machine uses a fixed feeder system where a placement head mounted to a gantry system picks up each component. When picked up, the component moves to a machine vision system which visually inspects the component and then placed on to the PCB using the vision-corrected coordinates (Coombs, 1996).

8.2.2.4 Reflow/Curing Oven

As previously described for the SMT assembly process the last step for the board assembly involves the curing or reflow of the component adhesives. The most common method for both
processes is the use of convectional heating with fans blowing directly onto the board (Coombs, 1996).

**8.2.3 SOLDERING**

The operation of soldering considers the method for creating the interconnection between the components in the circuit. The process, similar to welding, is a metallurgical joining technique which involves a molten filler metal which wets the surface of both metals to be joined and, upon solidification, forms the bond. The two most common metal fillers used in the electronics industry are leaded of lead-free tin. However, through the environmental initiative of the European Union with the WEEE legislative, which intends to reduce and eliminate the use of lead-based fillers and other toxic metals in electronics manufacturing, lead-free soldering has become the industry standard (Coombs, 1996). Neglecting design and quality aspects of the process of soldering, this thesis will describe the operational process of soldering commonly used in the industry. Soldering can be performed in either automated or manual processes.

**8.2.3.1 Automatic Soldering**

The automatic soldering processes which are considered in this thesis are:

- Reflow soldering
- Wave Soldering
- Selective Soldering

As mentioned previously, automated reflow soldering is used in-line in the SMT assembling process where convectional heat melts the solder paste which transforms into solder joints.

For most through-hole components and a limited range of SMT assemblies the process of soldering has been automated using wave soldering and selective soldering processes.

In wave soldering, the PCB are placed in a fixture, similar to a stencil plate with component openings, onto a carriage which moves the board through the machine. The machine utilizes a reservoir of molten solder pumped and circulated to form a fixed standing wave which, when the carriage moves the fixture over the wave, contacts the bottom of the board. Each opening in the fixture enables the wave to provide enough solder to form a joint between the components and the board (Coombs, 1996).

Selective soldering, much like wave soldering, uses a pump for the distribution of solder. The difference in selective soldering is that the pump is attached to a gantry system which moves the pump in three directional axes under the board. The solder flows through a nozzle, adapted to the lead size of the components and the nearby component clearance, and sprayed onto the leads in order to form the solder joints for the interconnection (Coombs, 1996).

**8.2.3.2 Manual soldering**

Manual soldering is used to cover the extent of assembled devices which the automated processes cannot solder, for example where the component clearance is too dense or when components is out of reach for the process. It also commonly applied for rework of any in-process non-conformities to address faulty components or inadequate soldering work which creates a non-working circuit. Manual soldering is also used when the soldering work needed for a board is so little that a mass soldering process cannot be justified (Coombs, 1996).
The most common manual methods utilize directed-energy bonding, where heat is localized to a specific area to accomplish soldering of one or a localized set of joints. One example of manual method still used for most manual soldering in the industry is the use of a soldering iron (Coombs, 1996).

8.2.4 INSPECTIONS
Manufacturers of printed circuit assemblies have always inspected their boards at various points in the assembly process. There are a variety of reasons for visual inspection of assemblies, including control of solder quality and detection obvious process defects quickly. But with the advent and growth of automated processes, dense component population on PCBs, and even hidden solder joints, visual inspection has become more difficult. Inspections have therefore been separated into two categories for processes which aim to improve detection of printed circuit faults: automated and visual inspections. Automated inspections, so called machine vision techniques, cover automated process test systems or real-time video capturing using x-ray, thermal imaging, laser or acoustics. One of them which are just directly in-line with the SMT process is the automated optical inspection (AOI). Unlike visual inspection, automated inspections removes human subjectivity from defect detection, thereby increasing repeatability rates significantly (Coombs, 1996).

Visual inspections using microscopes is also used for inspections performed by a human. Visual inspections are more common for rework and inspections in the process where the performance of automated inspections is not feasible (Coombs, 1996).

8.2.5 TESTING
Some faults connected to the production of printed circuit assemblies are not visible by any means of inspections. Defect components or faulty PCB circuits are two of the common defects where inspections fall short and testing becomes the most reliable method in order to ensure product quality. The two most commonly used testing methods in the electronics industry are in-circuit testing (ICT) and functional testing (FCT). ICT aims to detect any manufacturing defects such as faulty solder joints, circuit shorts, faulty components, and defects related to electrical circuit characteristics. FCT is used subsequently to the ICT for an approved printed circuit assembly in order to detect any performance defects related to the components. The FCT tests the product functionality analogically and digitally to the performance specifications of the product design in order to detect any defects related to circuit or component issues (Coombs, 1996).

8.2.6 BOX BUILD
Box build refers to manual assembly which involves operators working in a sequence within a PCB assembly line. Box build is generally located as the last assembly operation of a printed circuit assembly line where one or several sub-assemblies are finalized with casings, buttons, displays, etc., in order to build the final product (Coombs, 1996).