Product development process at Scania engine manufacturing

Master of Science thesis

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PREFACE

This Master of Science thesis has been carried out during 20 weeks in the period September 2012 to January 2013 on behalf of Scania CV AB in Södertälje. The thesis is the final part of the masters program in Mechanical engineering specialized in Production engineering and management at the Royal Institute of Technology – KTH in Stockholm.

I would like to thank all participants in the study, employees at Scania, Sandvik Coromant and Atlas Copco for sharing their valuable knowledge with me and making this thesis possible. My supervisors have been Michael Franzon at Scania and Mats Bejhem at KTH, whom I want to thank for their support and belief in me during the 20 weeks spent at Scania.

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Dan Kvistedal
ABSTRACT

Manufacturing companies today experience a more competitive market than ever, with increased demands on customization, quality and shorter life cycles. Shorter life cycles makes time to market for new products a crucial factor in retaining or even gaining market share.

Many companies have structured their product development process to have a systematic work method that is integrated with other functions in the company such as production, purchasing and marketing. At Scania this work started during the 1980’s and has been ongoing with continuous improvements ever since. Due to increased demands from a more competitive market the need to structure the participation of the production units in the product development process to shorten the lead time of product development projects.

This study aims to investigate how the engine production unit at Scania can be integrated in the product development process as early as possible. By studying literature in the area of product development, a general picture of the product development process has been obtained, as well as some methods for integrating production and design departments during the product development process.

A comparative case study has been performed at Scania, Sandvik Coromant and Atlas Copco Rock Drills. Their internal product development processes has been mapped as well as their organizations and roles connected to the development and introduction of new products. The interface between production and design has been investigated with focus on meeting forums, information exchange and other work methods that are established within the companies.

As a result some recommendations have been given to Scania on how to improve the participation of the engine production in the product development process. The recommendations start with educating the staff on already existing methods in process planning and the product development process. Secondly the engine manufacturing at Scania must decide to invest time and resources in developing their internal development process. The development of the engine manufacturing internal product development process should start with the general product development process at Scania, secondly it should focus on aligning the activities in process planning with the phases of the general product development process. Finally more detailed activities should be defined under each phase with clear defined responsibilities and lead times.

By defining an internal product development process Scania’s engine manufacturing will be better prepared to participate in product development projects. By having defined activities, responsibilities and lead times it will be easier to contribute to the planning of the product development project, as well as it will be easier to allocate project resources internally.

Keywords: product development, production, time to market, manufacturability, Scania
SAMMANFATTNING

Företag i den tillverkande industrin befinner sig i en marknad med hårdare konkurrens än någonsin, med ökade krav på kundanpassade produkter, kvalitet och kortare produktlivscykler. Kortare livscykel gör *Time to market* för nya produkter till en avgörande faktor för att bibehålla eller till och med vinna marknadsandelar.

Många företag har strukturerat sin produktutvecklingsprocess för att ha ett systematiskt arbetsätt där konstruktion är integrerat med andra funktioner inom företaget såsom produktion, inköp och marknad. Scania påbörjade sitt arbete med att strukturerar produktutvecklingsprocessen under 1980-talet och har utvecklat det med ständiga förbättringar sedan dess. På grund av hårdare krav från en mer konkurrenskraftig marknad har man sett behovet att strukturera hur produktionsenheter deltar i produktutvecklingsprocessen för att nå kortare ledtider i produktutvecklingsprojekt.

Denna studie syftar till att undersöka hur motortillverkningen på Scania kan integreras i produktutvecklingsprocessen så tidigt som möjligt. Genom att studera litteratur inom produktutveckling har en allmän bild av produktutvecklingsprocessen erhållits, dessutom har några metoder för att integrera produktion och konstruktion i produktutvecklingsprocessen.

En jämförande fallstudie har genomförts på Scania, Sandvik Coromant och Atlas Copco Rock Drills. Deras interna produktutvecklingsprocesser har kartlagts samt deras organisationer och roller kopplade till utveckling och introduktion av nya produkter. Gränsnittet mellan produktion och konstruktion har undersöks med fokus på mötesforum, informationsutbyte och andra arbetssätt som är etablerade inom företagen.

Som ett resultat har rekommendationer getts till Scania på hur man kan förbättra deltagandet från motortillverkningen i produktutvecklingsprocessen. Rekommendationerna inleder med utbildning av personalen i befintliga arbetsmetoder, främst gällande produktionsberedning, men även produktutvecklingsprocessen. Nästa steg som rekommenderas är för motortillverkningen att investera tid och resurser för att utveckla en intern produktutvecklingsprocess. Utvecklingen av en intern produktutvecklingsprocess bör starta med att titta på Scaniias globala produktutvecklingsprocess, efter det bör aktiviteterna i produktionsberedningsprocessen linieras med faserna i produktutvecklingsprocessen. Till slut bör detaljerade aktiviteter i varje fas definieras med tydliga ansvarsfördelningar och ledtider.

Genom att definiera en intern produktutvecklingsprocess kommer Scaniias motortillverkning vara bättre förberedd för att delta aktivt i produktutvecklingsprojekt. När aktiviteter, ansvarsfördelning och ledtider är definierade blir det lättare att delta aktivt i planeringen av produktutvecklingsprojekt, samtidigt som det även kommer vara lättare att tilldela interna resurser till projektet.

*Nyckelord: produktutveckling, produktion, time to market, bearbetbarhet, Scania*
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<tr>
<td>ABC</td>
<td>Activity based costing</td>
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<tr>
<td>AD</td>
<td>Assignment directive</td>
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<td>BOM</td>
<td>Bill of materials</td>
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<tr>
<td>CAD</td>
<td>Computer aided design</td>
</tr>
<tr>
<td>CAE</td>
<td>Computer aided engineering</td>
</tr>
<tr>
<td>CP</td>
<td>CoroPak, an event when Sandvik releases a package of new products</td>
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<td>CPP</td>
<td>Conceptual process planning</td>
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<tr>
<td>CQ</td>
<td>A decision forum for concept development projects at Scania</td>
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<td>CR-1</td>
<td>Concept review at Scania</td>
</tr>
<tr>
<td>ECO</td>
<td>Engineering change order</td>
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<tr>
<td>FMEA</td>
<td>Failure mode and effect analysis</td>
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<td>FQ</td>
<td>Field quality</td>
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<td>GPP</td>
<td>Global product preparation</td>
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<td>MONA</td>
<td>The assembly production support system at Scania</td>
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<td>MPP</td>
<td>Machining planning process</td>
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<td>P&amp;L</td>
<td>Production and logistics</td>
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<td>PD</td>
<td>Product development</td>
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<td>PDF</td>
<td>Project definition</td>
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<td>PPAP</td>
<td>Production part approval process</td>
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<td>PPM</td>
<td>Product planning meeting</td>
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<tr>
<td>PQ</td>
<td>A decision forum for product development at Scania</td>
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<tr>
<td>QFD</td>
<td>Quality function deployment</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and development</td>
</tr>
<tr>
<td>R&amp;M</td>
<td>Repair and maintenance</td>
</tr>
<tr>
<td>SOCOP</td>
<td>Start of customer ordered production</td>
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<tr>
<td>SOP</td>
<td>Start of production</td>
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<tr>
<td>SPP</td>
<td>Scania Project planning</td>
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<td>SPS</td>
<td>Scania production system</td>
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1 INTRODUCTION

1.1 Background

Johannesson et al. (Johannesson, Persson, and Pettersson, 2004) states that the market today for manufacturing companies is characterized by increased demands for product customization, quality, shorter product life cycles and harder international competition. Shorter product life cycles make the time to market for new products more and more crucial, and the ability to quickly introduce new products is decisive in capturing new market shares according to Gupta et al. (Gupta, Nau, and Zhang, 1993). Many companies have put a lot of effort to optimizing their product development process during the 21st century according to Johannesson et al. (Johannesson, Persson, and Pettersson, 2004) and run their product development work as systematic process, thoroughly integrated with related functions as production, purchasing, marketing.

At Scania the work with standardizing the product development work started in 1981, but it was not defined as Scania’s Product development process until the middle of the 1990s according to Jarnulf (Jarnulf, 2012). The PD process was divided in three sub-processes that were visualized by arrows in different colors:

- Pre-development (Yellow arrow)
- Continuous introduction (Green arrow)
- Product follow up (Red arrow)

![Figure 1 – Scania’s PD process visualized with arrows.](image)

Even though product development at Scania was conducted in a structured way, the PD process was characterized by long lead times and delayed introductions of new products. The effort to continuously improve the PD process had not been sufficient, even though continuous improvements is one of the main principles in the Scania Production System – SPS. To improve the lead times of PD projects, a decision was made to make a complete rework of the PD process. On 14th of September 2011 Scania started the development of PD process 2.0, Jarnulf (Jarnulf, 2012) explains that the goal was to create a robust process that would allow at least 9 out of 10 PD projects to be completed on time. During 2012 Scania plans to implement product development process 2.0 as a mean to achieve much shorter time to market for new products.
Production units at Scania, machining departments as well as assembly, are involved in different stages of the PD process. The reasons for this varies, from prototype production in the early stages of the PD process to implementation of the new product in the manufacturing line for series production. Historically these issues have been handled in an ad hoc manner, which sometimes have led to unnecessary long lead times. With the new PD process and the goals to reduce time to market for new products, there will be no time for ad hoc problem solving in the production units. The work processes within the different production units that are related to the PD process and implementation of new products must be improved in order to achieve the goal of reduced time to market for new products.

1.2 Purpose
The purpose of this master thesis is to investigate how a production unit can be integrated in the PD process as early as possible at Scania. The ambition is to support production units with the implementation of new products with the shortest possible lead times. The study will also investigate the new PD process and understand how it will influence the production units.

1.3 Objectives
With the ambition to reduce time to market for new products, waste must be eliminated from the PD process. Ward (Ward, 2002) explains two common types of waste in product development is hand-off and discarded knowledge. Hand-off is when you separate knowledge and responsibility, and discarded knowledge is the failure to reuse previously acquired knowledge in future projects. Examples of this could be when a design engineer tries to evaluate what impact a product design change will have on the production line, and ad hoc problem solving within production units during product implementation.

With the Background, purpose and problem analysis in mind, three objectives have been defined that shall be achieved in the result section of this study.

- Map PD process 2.0 at Scania.
- Investigate the interface between production units at Scania and the design department within the PD process.
- Investigate how production units can be integrated into the PD process to contribute to shorter lead times in product development.

1.4 Delimitation
This master thesis will investigate how Scania’s new PD process will influence the production units at Scania in Södertälje and how the production units can be integrated into the PD process. Assembly workshops will be delimited from the scope of the thesis mainly because of the professional and academic background of the author is more related to machining rather than assembly. The main focus area will be the engine machining plant where components for the basic engine are manufactured. The results of the thesis will also focus on the engine machining plant, but will hopefully be applicable on other machining plants within Scania. The main reason for focusing on the engine manufacturing is that the methods selected for the thesis work are time consuming and there is not enough time to cover all machining departments in the study in a satisfactory way.
The main focus area of the thesis will be the green arrow process, continuous introduction see Figure 1, and the interface between the engine production and the PD process within the green arrow projects. The yellow arrow process (pre-development) will also be covered, but the cross-section and information dependency between engine production and product development is smaller compared to the green arrow process. The red arrow process (product follow-up) will be explained in the study, but will not be investigated regarding improvements in the interface between engine production and product development. There are two reasons for this: (1) PD process 2.0 has not introduced any major changes in the red arrow process and (2) the red arrow process is well defined and has much shorter lead times compared to yellow and green arrow projects, often taken in 24-hour intervals.

1.5 Outline of the thesis
This section contains a brief overview of the structure of the thesis and some information about the content of the different chapters in the thesis.

1. INTRODUCTION
This chapter comprises the background of the study as well as the purpose. The problem is analyzed and defined in three research questions.

2. METHODOLOGY
This chapter contains an explanation to the different methods used during the study and a discussion regarding the suitability of the selected methods. The reliability and the validity of the study will also be discussed in this chapter.

3. THEORETICAL FRAMEWORK
This chapter will give a theoretical ground for the study; the general process of product development will be explained, as well as a description of Scania’s product development process.

4. RESULTS OF THE CASE STUDY
In this chapter the results of the case studies will be presented. The current situation at Scania, Sandvik Coromant and Atlas Copco will be presented with a description of process models, organizational structures and working methods.

5. ANALYSIS AND DISCUSSION
This chapter analyzes the findings in the case study by drawing parallels between the companies participating in the study as well as the findings in the theoretical framework.

6. CONCLUSION AND FURTHER STUDIES
This chapter comprises the result of the study. Specific recommendations are made to Scania regarding the development of the local product development process for the engine production plant. Further studies are recommended in certain areas that were not included in the scope of this study.
Chapter 1 – Introduction
Chapter 2 – Methodology

This study will be conducted at the engine production unit at Scania and will investigate the possibilities to integrate the production unit in the PD process as early as possible. In addition to Scania, Sandvik Coromant and Atlas Copco Rock drills will be investigated to benchmark their integration between production and product development. Sandvik are operating in a highly innovative business where they release several hundreds of new products yearly, in such a market it is important to have a structured way to develop new products and introduce them in the production, therefore they are found very interesting for this study. Atlas Copco was found interesting to the purpose of the study since they are also a heavy vehicle developer and manufacturer. Atlas Copco are operating in a market where time to market is crucial for new products since the market opportunity for a certain type of machine could be as small as a handful of machines. A late product introduction could miss the whole market opportunity.

The study will be based both on primary data, i.e. data that have been collected solely for the purpose of this study, both by interviews and written correspondence, and secondary data, i.e. data that have been previously collected with another purpose than the completion of this study (Björklund and Paulsson, 2003).

The research design of the study is a case study; this design is commonly used for studying processes according to Patel and Davidson (Patel and Davidson, 2011), and is suitable for the purpose of this study. Wallén (Wallén, 1996) states that the advantage of using the case study design is that it gives detailed and comprehensive knowledge of the process. In the case study it is important to collect data of different types to get a comprehensive picture of the case. Patel and Davidson (Patel and Davidson, 2011) uses an example where an organization is studied, then interviews, observations and surveys could be combined in the data collection process. Wallén (Wallén, 1996) also mentions a risk with the case study design, since it will provide a lot of data about the studied object or organization there is a risk that one will collect to much data and it might be difficult to know which information is most important, thus it can be time consuming and difficult to finish the study. Another drawback with the case study is that there is a risk that the general applicability will be low, depending on how you design your study. Wallén (Wallén, 1996) also states that since the knowledge found in the case study was found under specific circumstances, the conditions of the study must be stated clearly and discussed as thoroughly as possible. Normally when research findings shall be applied to a concrete situation, the findings must be interpreted from general knowledge to a more specific situation. With a case study the information must be transferred from one specific situation to another.

To reduce the risk of overwhelming data collection and excess time consumption, the delimitations is a key factor. By delimiting the scope of the study an appropriate amount of data can be collected within the available time frame. To increase the general applicability of the results, the studied population in the case study will be increased by investigating other companies besides Scania.

Due to the nature of the problem definition, the data collection will be conducted mainly in a qualitative manner. In qualitative research the data collection is typically focused on “soft” data, for example in the form of qualitative interviews and interpretative, verbal analysis of written material, this is explained by Patel and Davidson (Patel and Davidson, 2011). Björklund and Paulsson (Björklund and Paulsson, 2003) also states that the use of qualitative studies is advantageous when you want to create a deeper understanding of a specific subject, event or situation, but the possibilities of generalization are slightly smaller compared to a quantitative study.
Chapter 2 – Methodology

The method model, Figure 2, of the study visualizes how data will be collected in order to answer the questions in the problem definition.

2.1 Theoretical study

The literature study will have three objectives:

1. To provide a general view of modern principles for product development.
2. To give some knowledge of methods to integrate production units in the PD process as early as possible.
3. To provide an understanding of how Scania’s PD process is working. The reason for the first objective is to put the remainder of the study in a theoretical context, while the two following objectives are connected to the problem definition of the study.

Andersen (Andersen, 1994) states that documents with a general view of the topic should be used early in the study, this will fulfill the first objective – to provide a good theoretical context for the study, but it will also allow the author to narrow the search for specific theories that should be investigated in order to reach the second objective. The general literature study will also provide good tips of further reading in the reference lists of the respective documents. The main focus for the first objective will be to find books on the topic that have been published. Patel and Davidson (Patel and Davidson, 2011) finds that books are more likely to give theories and models developed in its entirety, as books often are presentations of attempts to compile all the knowledge within one problem area. When the general theoretical context of the study is established the most important theories can be investigated further, using books, but also by searching for articles, reports and conference papers, which are more likely to contain the latest findings, as they are published much faster than books.

The second part of the theoretical study will fulfill the third objective – to define the PD process at Scania. It will be based on primarily on internal documentation and presentations. A lot of material that explains PD process 2.0 has been produced at Scania, primarily the process itself has been defined in a series of documents, but a lot of presentations have also been made. These presentations were used during the development and implementation of the new PD process, to spread information, but also to prepare for the transition from the old process to the new. Presentation material has also been produced as educational material for Scania’s internal course “PD journey” which is used to educate Scania employees about the PD process.
The advantages and drawbacks of both methods – document study and presentations, explained by Björklund and Paulsson (Björklund and Paulsson, 2003), are similar. The main advantage is that a lot of knowledge can be acquired in a short amount of time and with little resources, the drawback is that all the data is secondary data and has been collected for a different purpose than that of the study. The advantages of the methods make them very suitable for this study, and the impact of the drawback varies somewhat depending on the three objectives of the theoretical study. For the first objective, to provide a general view of modern principles for product development, and to create a theoretical context, the impact is quite small. Since it is an explorative objective, to establish a basic understanding, the purpose of publishing the information becomes somewhat irrelevant. For the second objective the impact of secondary data is bigger, since methods of integrating production with product development might have been researched in some specific context, and the applicability to Scania’s engine production must be discussed in detail in the study. Regarding the third objective the impact will be slightly smaller; documents have been produced to explain the PD process in general, focusing mainly on R&D side of the process and not so much on the interface between production and product development. Since the theoretical study of the PD process is mainly descriptive, Scania’s internal documents will suffice. A more explanatory study of the interface between production and product development at Scania will be conducted in the empirical study.

2.2 Empirical study
The empirical study will have two objectives:

1. To investigate the interface production and product development within Scania engine production, Sandvik Coromant and Atlas Copco Rock drills, regarding information channels, meeting structures and system support.

2. To evaluate the applicability of new methods for integration of production and product development that was found in the theoretical study. Both objectives are closely linked with the objectives in the problem definition.

2.1.1 Interviews
The most important method for data collection in the empirical study will be interviews. The concept of interviews contain many different methods for questioning the participants, from meetings in person, telephone interviews, written correspondence via e-mail or SMS according to Björklund and Paulsson (Björklund and Paulsson, 2003). Depending on the chosen method, the number of respondents in an interview may also vary from one to several respondents at the same time. Another variable in the concept is the form of the interview; Björklund and Paulsson (Björklund and Paulsson, 2003) divides it into three different categories, structured interviews, semi-structured interviews and unstructured interviews. In the structured form, the interviewer will have all the questions prepared and ask them in a certain order, while in the semi-structured form, only the topics that shall be examined are prepared and the questions are formulated during the interview and the order of the questions can be changed depending on the reactions from the respondents. In the unstructured form the interview is carried out more like a conversation, where the topics and questions will arise during the interview.
Patel and Davidson (Patel and Davidson, 2011) have a two-dimensional categorization of interviews – (1) standardization and (2) structuring. The degree of standardization refers to the preparation of the order of the questions and the formulation of the questions, this can be compared to what Björklund and Paulsson (Björklund and Paulsson, 2003) calls structure of the interview. However Patel and Davidson (Patel and Davidson, 2011) defines structure as the freedom of interpretation and response space given to the respondent. Some examples of the different categories of interviews are found in the figure below.

Regardless of the type of interview, it is quite important to start and close the interview with some neutral questions. According to Patel and Davidson (Patel and Davidson, 2011) most interviews start with some background variables that are necessary, and end with an open question to give the respondents an opportunity to mention something that might be of importance but was missed during the interview. Björklund and Paulson (Björklund and Paulsson, 2003) also finds that it is very important that the interviewer has some awareness of how leading the questions are, but most of the time it is best to avoid leading questions.

The interviews in this study will be performed with a low degree of standardization and structuring, using Patel and Davidson's terminology. Respondents will be engineers within Scania, Sandvik Coromant and Atlas Copco Rock drills that are working on both sides of the interface between engine production and product development. The main topics for each interview will be determined before the interview starts, but the formulation and order of the questions will be decided during the course of the interview. The main reason behind this decision is that it will give the author a lot of freedom to be flexible during the interviews. It will also allow the same basic topics to be investigated from different perspectives depending on the professional role of the respondent, without extensive preparation before each interview. Patel and Davidson (Patel and Davidson, 2011) explains that a qualitative interview like this has the purpose of investigating the characteristics of something, in this case, it is the interface between the engine production and product development at Scania. The purpose of the interview makes it very hard to prepare a selection of answers to the respondent, and it is better to allow the respondent the opportunity to answer with his or her own words.
The main advantage of interviews is that all the data collected is primary data, since the respondents answer questions that have been formulated purely for the sake of the study. With follow-up questions that can be adapted to the individual respondent, the interviewer also has the possibility to gain a deeper understanding of the topic according to Björklund and Paulsson (Björklund and Paulsson, 2003). One drawback with using interviews as a study method is that it can be very time consuming, and in some cases even expensive due to travel costs. Another drawback, or rather a difficulty, with the method is that some respondents might be reluctant to answer the questions in the interview. Patel and Davidson (Patel and Davidson, 2011) suggests some methods to increase the motivation of the respondents: (1) Explain the purpose of the study, and try to relate it to the purpose of the individual respondent. (2) Emphasize the importance of the respondent, and the contribution he or she will make to the study. (3) Explain how the respondents contribution will be used, will it be anonymous or named in the study.

2.1.2 Observations
Observations are the most common method for data collection in our daily lives based on random encounters. But as a scientific method the observations cannot be random, Patel and Davidson (Patel and Davidson, 2011) state that they must be systematically planned and performed. Observations will be used as an additional method to interviews in this study to further investigate certain parts of the interface between engine production and product development, for example meetings between different representatives. Andersen (Andersen, 1994) suggests that observations can be used early in the study to get a more clear view of the problem, but in this study observations will be used rather as a follow-up method to the interviews. This is supported by Patel and Davidson (Patel and Davidson, 2011), they state that observations can be used both as an explorative method early in the study and be the base of the following research, but observations can also be used to supplement information that have been gathered with other methods. They also state that the method is suitable when one wants to investigate behaviors and activities in their natural situations, which is analogous to the purpose of the empirical study.

Before using observations as a method for data collection one must answer three questions (Patel and Davidson, 2011):

- What shall be observed?
- How shall the observations be registered?
- How shall the observer relate to the object of the observation?

The first two questions are closely connected to whether or not the observation is structured or unstructured. Structured observation requires that the observer has some knowledge of the situations and behaviors that shall be observed. A number of categories can be prepared in an observation chart, which is basically a list of expected behaviors that can be ticked off as they occur, if the sequence is important it can be registered as well. In an unstructured observation a more explorative approach is taken, and “everything” can be observed. The unstructured observation also requires preparation; the type of information that shall be registered must be known in advance, and the method of registration as well (Patel and Davidson, 2011).
Chapter 2 – Methodology

The third question is independent of the type of observation used and refers to how the observer behaves in relation to the situation being observed. Björklund and Paulsson (Björklund and Paulsson, 2003) highlights two variables in this question; whether the observer is participating or non-participating in the situation, and whether the observer is known or unknown to those which are observed. Independently of the relation between the observer and the object of the observation, behaviors can be seen directly as the observer always is in direct contact to the objects that are observed according to Andersen (Andersen, 1994).

A Participating observer will actively join the observed group as a member, and will face a set of difficulties with the method. First of all, the active participation in the group might impede the registration of the observed information. And secondly there is a risk that the participation of the observer will influence the behavior of the group. The non-participating observer will on the other hand have more time to register the information that is observed and is less likely to influence the behavior of the group.

Whether the observer is known or unknown to the group there will also be a set of difficulties. The observer that shall be known to the group will have to gain the permission of the group to observe them and must be impartial to the members of the group to be able to observe a natural behavior. The unknown observer can face a difficulty of finding the best location to observe the group without being noticed; in some cases it can even be impossible to be an unknown observer. One advantage of being a known observer compared to unknown is that the known observer is able to ask questions regarding the activities that are noticed, the unknown observer cannot do this without revealing themselves. Another difficulty for the unknown observer is the ethical issue of the personal integrity of the individuals being observed. Is it ethically right to observe a person without their consent? There is no right answer to this question, but the author must make sure that the identity of the observed individuals must be hidden when reporting the results of the study.

The observations in this study will be performed in an unstructured manner with the purpose of investigating information exchange between engine production and product development in different meeting forums. An unstructured observation method is sufficient since the aim is to get a general picture of the information exchange, rather than the behavior of different participants during the exchange. The author will not participate actively during the observations and whether the role as observer will be known or not depends on the type of meeting. If the meetings are in smaller groups and characterized by in depth information exchange and discussions it will be motivated to explain the purpose of the observation to the participants. The main reason is that it can be necessary to ask questions about certain observations in order to get a deeper understanding. But it might also seem odd to suddenly have an additional person attending but not participant in a meeting with a small group. In other cases it can be motivated to be an unknown observer, for example meetings in bigger groups where participants are simply briefing each other about the status in respective projects without much discussion between participants. If any follow-up questions are necessary after such an observation, the relevant person will be interviewed in person rather than asked in front of the whole group. The integrity issue will be handled in the way that no information that can reveal the identity of any participant will be revealed.
The main advantage of using observations is that the observations are done exactly when something occurs, the study is not depending on the recollection of a respondent like an interview (Patel and Davidson, 2011) and the information collected is objective. Drawbacks of the method are that it can be a very time consuming and expensive method (Björklund and Paulsson, 2003) and the observer must always interpret the observed behavior, it might not be representative of a natural behavior (Patel and Davidson, 2011).

### 2.2 Reliability, validity and objectivity

According to Björklund and Paulsson (Björklund and Paulsson, 2003) there are three measures of the credibility of a study:

- **Validity** – to what extent you actually measure what you intend to measure
- **Reliability** – the reliability of the measurements, if you repeat the study, will you get the same results?
- **Objectivity** – to what extent the values of the author and participants influence the results of the study.

In every study the effort must be to reach as high validity, reliability and objectivity as possible with regards to the resources and time that is available. Patel and Davidson (Patel and Davidson, 2011) gives one method that is commonly used to increase validity and reliability is triangulation, which can be done in many different ways. During data collection several different methods can be used such as interviews, observations and documents. The information from different sources will be compiled in the analysis to get a comprehensive view of the issue. The outcome from different methods can point toward different directions and still be equally interesting to the study, for example if a person says one thing in an interview and does something contradictive during an observation, that can be the basis for a deeper interpretation.

Another method of triangulation can be that the researcher validates the study by using several data sources, for example interviewing people with different perspectives of a phenomenon. One method to increase the objectivity of the study according to is to motivate different choices that are made during the study thus giving the reader a possibility to self-evaluate the objectivity and the results of the study (Björklund and Paulsson, 2003).

The validity of this study has been ensured by having a dialogue with the supervisors, both at KTH and Scania to ensure that the study is making the necessary progress related to the problem definition. The study will also be triangulated to increase the reliability, partially by using different methods of collecting data, but mostly by interviewing individuals with different perspectives on the interface between the engine production and product development at Scania, Sandvik Coromant and Atlas Copco.
3 THEORETICAL FRAMEWORK

This chapter will give a general view of product development and integration methods between production and design as a theoretical context for the empirical study, and Scania’s product development process will be mapped.

3.1 Strategic product development process

The product development process is just one of several interacting processes within the company, it can be seen in the context of the whole company. In turn, the company interacts with various counterparts in the business environment; this is summarized in Figure 4 - Product development within a company.

One of the key processes that product development interacts with is the product planning process. It is a strategic process, which determines the criteria for product development, and is influenced by different forces, or drivers, both external and internal.

3.1.1 External drivers for product development

External forces are continuously influencing companies to develop new products. Historically the two main influences have been technology and market, but a third influence, society, is getting more and more important according to Johannesson et al. (Johannesson, Persson, and Pettersson, 2004). Technology driven product development is based on new technologies that are not applied in products currently on the market. This kind of product development is often characterized by a long perspective, as it can take a long time to develop the technology for new applications and to establish it on the market. Market driven product development is based on the demands from the market and competing products, it is focused on applying known technology in the best way. Market driven product development has a shorter perspective and often characterized by smaller modifications of existing products, a typical example is cars, where a new model is released every year (Johannesson, Persson, and Pettersson, 2004). The influence from society regards mainly to legislation for tougher environmental and safety demands in order to steer product development towards more sustainable solutions.
Chapter 3 – Theoretical framework

Regardless of the driver, there are two different types of product development projects, development of new products and further development of existing products. Development of new products is characterized by creativity, innovation and high risk and uncertainty. Further development of existing products is the most common type of PD project. In this type of project a company aims to improve existing products, often at a sub-system level. Uncertainty and risk is avoided by using verified technologies in this type of project.

### 3.1.2 Internal drivers for product development

A company may also have internal drivers for the product development, based on the strategic positioning of the company three different drivers may influence the company in various ways. Three different factors have been identified by Holmdahl (Holmdahl, 2010):

- **Wish** – There is no existing product of this specific type on the market, but the company wishes to develop it.
- **Want** – One or a few similar products exist on the market, but the company wants to develop another version that would be more suitable for a certain situation or customer group.
- **Need** – The product is fairly normal but the company wants to develop a new variant.

Depending on the type of driver Holmdahl (Holmdahl, 2010) states that the conditions of the project will vary, as seen in Table 1.

**Table 1 - Conditions for PD project depending on the project driver (Holmdahl, 2010).**

<table>
<thead>
<tr>
<th></th>
<th>Wish</th>
<th>Want</th>
<th>Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable conditions</td>
<td>-</td>
<td>(✓)</td>
<td></td>
</tr>
<tr>
<td>Unstable conditions</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Some specific examples of the unstable conditions that apply for wish and want projects are:

- Large uncertainties make it difficult to set a finish date.
- Action plans are much more applicable than time schedules.
- The product specification will develop during the project based on the project activities.
- To succeed with a wish or want project, you need strong advocates for the project within the organization.

In a need project uncertainties are much smaller, and much more knowledge and experience is available, therefore planning and execution is easier (Holmdahl, 2010).
3.2 **Operational product development process**

A systematic approach to product development has been developed since the 1990’s (Johannesson, Persson, and Pettersson, 2004), driven both by industry and academia. The methods that have been developed in industry and academia have influenced each other mutually; this has resulted in a pretty uniform model of the different phases in the product development process that is illustrated in Figure 5.

![Figure 5 - Model of the PD process described in literature](image)

The PD process described in literature is iterative, which means that each phase can be carried out several times depending on the outcome of the decision point that separates each phase from the other.

### 3.2.1 Pre-study

Johannesson et al. (Johannesson, Persson, and Pettersson, 2004) describes the pre-study as an unbiased problem analysis performed in a cross functional work group with participants from different parts of the company, such as marketing, R&D, production, sales and sometimes representatives from customers and suppliers as well. Even though relatively little resources are used in this phase most of the future costs of the product is determined in this phase. This is visualized in different literary works (Johannesson, Persson, and Pettersson, 2004), (Anderson, 2008) and an example is shown below in Figure 6 where the future cost of the product is determined in the early phases of the project but actually incurs in the later phases.

![Figure 6 - Tied future production cost in PD projects](image)
Chapter 3 – Theoretical framework

The main objective of this phase is to define the functional requirements of the product – what the product should do. The function description is the first stage of the specification of the product, which will be more detailed and developed as the phases in the project proceeds (Johannesson, Persson, and Pettersson, 2004). Anderson (Anderson, 2008) states that Quality Function Deployment (QFD) can be used in this phase to systematically prioritize design requirements based on customers priority.

3.2.2 Concept development

In the next phase of the PD process different product concepts will be developed from the function requirement that was defined in the previous phase. Many concepts are generated simultaneously with different solutions to achieve required functions. The product concept is still quite vague and does not contain sufficient information to make a prototype product. A product concept in this phase of the project may contain information such as (Johannesson, Persson, and Pettersson, 2004):

- Preliminary product layout
- Preliminary cost estimation
- Sketches and descriptions of technical solutions
- Description of the features of the solution in relation to the function specification
- Reasons for the choice of technical solutions

The last part of this phase is a concept review and selection, where the best concept will be chosen for further development in the coming phases. All concepts shall be evaluated to determine their value relative to the product specification, and the concept with the highest value shall be selected for further development.

3.2.3 Detailed engineering

In the third phase of the PD process the selected concept shall be further developed into a functional product that fulfills the requirements in the product specification determined in the pre-study. This means that parts must be dimensioned, standard components must be selected. Parts that are unique must be designed for the product. During this phase the architecture and layout of the product must also be defined. The architecture of the product refers to how the product is built with different sub-system solutions and how these sub-systems interact with each other according to Johannesson et al. (Johannesson, Persson, and Pettersson, 2004). The layout of the product is how the different components of the layout are located in relation to each other in space.

In this phase it is also common with prototype construction, this can be done for different purposes:

- **Virtual prototyping** – modeling and simulation in a digital environment. For example using CAD to view a 3D model of the product in different perspectives, or using CAE to evaluate the products performance in different aspects

Physical prototypes are also necessary sometimes:

- **Mock-up** – to visualize shape, surface properties and color
- **Function prototype** – to be tested in a laboratory to verify a technical solution
- **Test products** – complete prototypes that are adapted to series production and can be tested in the field
3.2.4 Production preparation

Prototype products are often produced in small numbers with a high grade of manual work; therefore they may be designed in a way that does not consider series manufacturing requirements. The product will have to be modified in a way that it can be produced and assembled with the intended equipment and methods, often with existing machinery and equipment in the company. The factors that influence manufacturing requirements should however be considered as early as possible in the project.

3.3 Integration of product development and production

In the literature there are several methods presented to integrate product development and production in product development projects. Nihtilä (1999) refers to four common methods and explains their applicability:

- **Standardized planning procedures** – This is an impersonal method of integrating the two departments. By having a defined product development process with clear description of phases, companies will create a common vocabulary that will allow a cross functional planning to be done early in the projects. Standardizing the planning method will also place demands on securing resources in all involved functions, which is one of the key factors for successful project planning (Nihtilä, 1999) along with keeping the planning phase short and intense. This type of descriptions and templates for standardized procedures are often embodied in web-based applications to make them more easily accessible, and to change their roles to tools rather than passive illustrations of the process.

- **Design reviews** – Typically a cross functional meeting where R&D and other stakeholders to evaluate the design against its requirements. Design reviews should be held several times throughout the product development process, with different purposes and different denominations: project proposal review, product concept review, detailed design review. Where the ultimate design review will trigger the product release if it is successful. Although a very useful procedure, the design review is depending on the experience of the participants. There must also be adequate organizational resources to allow participants to make a thorough preparation before the design review.

- **Individual integrator** – This mechanism can be both formal and informal. A more mature organization will have clearly defined roles and responsibilities, thus reducing the dependence on the individual’s professional network within the company. By having the right people at the right place, the availability and credibility of key roles in the project are increased (Nihtilä, 1999).

- **Cross functional teams** – By building formal project management teams with representatives from all relevant functions, the cross functional involvement in the PD projects can be ensured. Nihtilä (1999) states that an explicit project kick-off is crucial to the initiation of the cross functional teamwork, it will give a disciplined start, and key issues can be handled at the beginning of the project, such as project goals, key assumptions and identifying key resources. A difficulty with cross functional work is to find the balance between product development and operational activities, and engineers that are allocated 75% to one project is often available less than 50% (Nihtilä, 1999). Anderson (Anderson, 2008) supports the idea that cross functional teams is a very important factor for successful design projects and that the most effective way to assure manufacturability is to attain early and active participation from manufacturing in the product development projects. Further he states that manufacturing engineers should be divided in three sub-groups to maximize their participation in product development and protect them from firefighting distractions:
o **New product development support** – should be staffed with the manufacturing engineers most experienced in product introduction. This group should be financed by the development project.

o **Process improvements** – Engineers working primarily with improving manufacturing processes. This group is expected to be financed by the pay back of process cost savings.

o **Firefighting** – Should be staffed with personnel experienced in firefighting, not necessary degreed manufacturing or industrial engineers. Should be financed by the product.

### 3.3.1 Conceptual process planning

Shaw and Zhang (Conceptual process planning - A definition and functional decomposition, 1999) have proposed an activity for designers to evaluate manufacturability during the conceptual design. They state that since manufacturing costs are primarily determined during the design phase it is almost imperative to evaluate manufacturability as early as possible in the design stage, preferably already in the conceptual design. In order to cope with the difficulty of making sound decision a method called conceptual process planning – CPP has been defined like this:

**Conceptual process planning (CPP)** is an activity of preliminary manufacturability assessment of conceptual design in the early product design stage. It aims at determining manufacturing processes, selecting resources and equipment, and estimating manufacturing costs roughly. Conceptual process planning supports product design to optimize product form, configuration and material selection and to minimize the manufacturing cost. (Shaw and Zhang, 1999)

The result of the CPP is quite general compared to detailed process planning which is based on a detailed design and the CPP. The detailed process plan will result in specified operations and operation sequences, selection of machines and tools to be used, descriptions of setups and defined process parameters. Having started from basic process planning activities, an activity model for CPP has been created by Shaw and Zhang (Shaw and Zhang, 1999). The CPP method has been divided into the three main activities that can be seen in the activity model in Figure 7. The activities shall be performed sequentially, as well as the sub-activities that are defined for each main activity:

![Figure 7 - Conceptual process planning activity model (Shaw and Zhang, 1999)](image-url)
**Determine manufacturing processes** – Manufacturing processes shall be selected based on high level information such as material, form and tolerances. The following sequence has been suggested by Shaw and Zhang (Conceptual process planning - A definition and functional decomposition, 1999).

1.1. Determine manufacturing processes based on material characteristics, a set of possible materials should have been specified by designers in the conceptual design.

1.2. Select manufacturing processes from 1.1. based on the quantity of the product that should be produced. Large volumes require higher production rates, special machinery and typically less skilled labor, whereas smaller volumes require more sophisticated labor skills and more general equipment.

1.3. Select processes from 1.2. based on the shape and feature characteristics of the product.

1.4. Select processes from 1.3. based on the tolerance requirements of the design in the early stage. Tolerances control the form of parts and the relationships between parts in a product. Tight tolerances usually require high precision machinery and more skilled workers. The tighter the tolerances are, the narrower is the available selection of manufacturing processes.

2. **Select manufacturing resources** – Appropriate manufacturing resources should be selected based on the determined manufacturing processes in the previous activity. Resources include machines, tools and labor. By referring to a company manufacturing resource model, some of the selections may be predefined.

2.1. Select machines available in factories or from suppliers for manufacturing of the designed product. Machines include machine tools, forging machines, casting machines, material handling, assembly and measuring machines.

2.2. Based on the machines selected in 2.1. tools and fixtures must be decided to support the selected manufacturing processes.

2.3. Decide necessary labor skills to operate the machines and tools selected in 2.1. and 2.2.

3. **Estimate manufacturing cost** – Estimate the manufacturing cost based on the selected manufacturing processes and resources in previous steps. Manufacturing costs covers material, purchased parts, labor, tooling, capital and overhead.

Finally Shaw and Zhang (Conceptual process planning - A definition and functional decomposition, 1999) state that there are three main advantages of using CPP: (1) the manufacturability of the product is assessed early in the development. This gives the project an opportunity to make early design changes in order to improve the manufacturability with less cost. (2) the CPP method estimates the manufacturing cost, which can support an affordability assessment or a make/buy decision. (3) the method will reduce the time to market for the new product by preparing production activities early in the project.

Hassan, et al. (A quality/cost-based improvement approach for conceptual process planning, 2009) and (Conceptual process planning - an improvement approach using QFD, FMEA and ABC methods, 2010) proposes an improved approach to the cost estimation of the CPP method. By using Failure mode and effect analysis (FMEA) and Activity based costing (ABC), the cost estimation task can be made more thoroughly. FMEA is described by Johannesson et al. (Johannesson, Persson, and Pettersson, 2004) as a systematic approach to predicting possible errors and their consequences, by identifying a probability, degree of seriousness and the risk of not detecting the error a risk priority number is calculated. Based on the selection of manufacturing processes and resources a process FMEA is performed to identify the risk of failures for the conceptual process plan. Parallel to that ABC can be used to estimate the manufacturing cost for the conceptual process plan. The ABC
method assumes that activities consume resources, and products in turn consume activities according to Ax and Ask (Ax and Ask, 1995). Indirect costs of activities are distributed to products based on their consumption of the activities. In the ABC method the cost of the product is the sum of the direct cost such as material and the cost of all activities performed to deliver the product.

The subsequent step is to use the input from both FMEA and ABC to estimate the cost for different failure modes. The result from all these steps should be used as input for making the detailed process plan in a later step of the product development (Hassan, Siadat, Dantan, and Martin, A quality/cost-based improvement approach for conceptual process planning, 2009) (Hassan, Siadat, Dantan, and Martin, Conceptual process planning - an improvement approach using QFD, FMEA and ABC methods, 2010). The ABC and FMEA approach to cost estimation in conceptual process planning is modeled in Figure 8.

![Diagram of ABC and FMEA](image)

Figure 8 - Implementing ABC and FMEA in CPP, Hassan, et al. (A quality/cost-based improvement approach for conceptual process planning, 2009) and (Conceptual process planning - an improvement approach using QFD, FMEA and ABC methods, 2010)

### 3.3.2 Machining planning process

MPP is a standardized method of working with process planning for machining and sheet-metal forming within Scania (Scania CV AB, 2011). The method is intended to support the process planners at Scania and is created by some of the most experienced process planners at Scania. A series of general activities is defined to explain how the process planning of a product will be carried out. The process is divided in six phases. All the necessary information needed at the start of each phase is defined, as well as what documents should be archived after each phase. The six phases of MPP have been visualized in Figure 9 in the process description at Scania.
1. **Initiation** – this is merely the impulse to start the planning process. It can come from four different reasons: (1) Continuous improvement (2) Change of manufacturing method (3) Quality problems (4) New product development.

2. **Pre-study** – in this phase the process planner will make a rough process plan that can be used for further work. A meeting with the designer must also be held to discuss the design of the product in terms of manufacturability. The results of the discussion will be the base of a slightly refined process plan, including operation sequence, assessment of necessary production equipment, cycle times, capacity, investments. A plan for the following phases must also be made, including the number of prototypes to be made.

3. **Development** – as the design of the new product proceeds, so does the development of the process plan. In this phase the process plan will be more detailed, including localization points in the machine, clamping methods shall be defined, tools and packaging material shall also be defined.

4. **Verification** – the objective of this phase is to finish the process plan and to verify the process in production. The process shall be verified in the same situation as serial production, it shall be with the right tools and fixtures. The workshop manager shall approve the verified process before serial production can start. This is done by using the PPAP method. (Production part approval process)

5. **Introduction** – in the introduction phase the responsibility of the serial production will be moved to the line organization from the process planner.

6. **Conclusion** – in the conclusion phase the line organization will confirm that they have taken over the responsibility of manufacturing the product. The project will be terminated and all relevant documentation will be archived.

A more detailed modeling of MPP was performed during a thesis work at Scania during 2007. Since the MPP was mainly a written description of a process, it was thought to have a weakness in its inability to describe the correlation between different activities. The process was visualized and each phase was modeled with all of its main activities. The main activities have in turn been modeled more in detail, as can be seen in Figure 10 where one main activity in the pre-study phase has been modeled in detail. The thesis work resulted in an Astrakan model with 19 pages of detailed modeling of all six phases in the machining planning process, including the prototype manufacturing process which has been described. The purpose of the model is to be a supplement to the written description that is the MPP work model (Hedlind, 2007).
Figure 10 - Pre-study phase of MPP at Scania (Hedlind, 2007)

In addition to defining the required activities, the MPP also gives some guidelines and key issues to address during the process planning work. One example of this is to use benchmarking, both external and internal. How are other manufacturers producing similar products, and how are similar products being produced at Scania? If this information can be gathered, then alternative methods shall be evaluated to see if any improvements can be made on quality, production flow, safety.

Some key issues are also defined for the process planner when viewing the product drawings, such as allocation surfaces on the product and drawing references and in some cases there can also be technical requirements placed on the manufacturing process. These issues will all help the process planner to prepare operation sequence, clamping, tooling and quality assurance.
3.4 Product development process at Scania

Scania’s product development process must be mapped to provide sufficient background information for the case study in chapter 4. The PD process will be mapped and explained, as well as the main principles for R&D work conducted at Scania.

The PD process is permeated by four words that govern how work is carried out in the whole R&D organization (Scania CV AB, 2011):

- **Product ownership** – It is fundamental to Scania that the PD projects can never have ownership of the product; it is merely responsible for coordinating development and industrialization. The line organization is the owner of the product.

- **Cross-functional and parallel** – Successful product development must be carried out in a cross-functional way, at Scania all cross-functions are involved in the PD projects, from initiation to product introduction.

- **Uncertainties** – Product development work is naturally characterized by uncertainties. By using iterative problem solving the uncertainties are minimized within the concept development before the project moves in to the next phase. In the product development phase the uncertainties are small enough to make a good project plan and achieve high delivery precision and efficiency in the project.

- **Configuration** – This is the planning part of each phase of the PD process; it is carried out by a cross-functional team that sets milestones for all involved functions in the PD project.

As mentioned previously the product development process at Scania comprise three different sub-processes, or phases that are illustrated in Figure 11:

- Pre-development (Yellow arrow)
- Continuous introduction (Green arrow)
- Product follow up (Red arrow)

![Figure 11 - Illustration of the PD process at Scania](image-url)
3.4.1 Pre-development (yellow arrow)

The pre-development phase deals with the investigation of business possibilities and technical solutions before an actual product can be developed; it consists of three different areas:

- **Research** – This area is all about gaining cutting-edge knowledge about how new technology can be applied in strategic areas. Much of the research is conducted internally at Scania, but also in cooperation with universities and strategic partners.
- **Advanced engineering** – Technologies that have previously been researched are now further developed and investigated in relation to properties of Scania’s products and the benefit of the customer. The more the understanding of new technologies increases, the more the uncertainties decrease, making the technology more viable to use in later development phases. After this phase, Scania will know if the technology is suitable for their products, and to what extent it can be used.
- **Concept development** – Before a new concept development project starts, there must always be clearly described need behind the concept. The need can come directly from a customer, legal requirements, Research and advanced engineering, cost reduction. (see Figure 12)

![Figure 12 - Input to Product Planning Meeting at Scania](image)

The first step towards a new concept development project takes place at the product planning meeting, PPM, which decides to start an investigation to analyze the demand. The investigation shall result in a demand statement, which should give sufficient information to make a good decision whether to start a concept development project or not. If the demand statement is accepted at the CQ meeting, a decision forum for concept development, the configuration of the concept development starts. During the configuration the required time and resources for the project is estimated and milestones are set, the configuration phase of the concept development is usually carried out rather quickly with a wide set of competences (Tilly, 2012). The configuration must then be approved at the next CQ meeting, after which the actual concept development projects start.

The concept development project is characterized by experienced engineers working in small groups with focus on innovation and risk elimination. The objective of the concept development is to deliver an assignment directive with a degree of uncertainty that is low enough to allow 9 out of 10 product developments to be finished on time (Jarnulf, 2012) (Tilly, 2012), but still with a “dare to stop” mentality. If the project will not provide sufficient customer benefit to be implemented in Scania’s
products, the project shall be terminated. Before the finished concept will be presented at a CQ meeting, it will be reviewed in a cross-functional decision forum called CR-1 (CR minus one) where all related functions at Scania, such as production, purchasing, marketing, will approve the concept. If the concept is approved both at the CR-1 and CQ meeting, it will be generated into an Assignment directive (AD), which is the main deliverable from the concept development, and is also the starting point of the next phase of the product development process – continuous introduction. In Figure 13 the concept development process have been illustrated with the different phases, decision points and deliverables.

Figure 13 - Concept development process at Scania

3.4.2 Continuous introduction (green arrow)

In the continuous introduction phase the results of the pre-development phase are made available to customers by implementation in the Scania product range. The sub-phases of the continuous introduction process is illustrated in Figure 14. This phase also starts with a configuration based on the information in the assignment directive. During the configuration all departments that will be involved in the project will make a project plan together, based on the knowledge acquired in the concept development phase. The assignment directive can be seen as an inquiry from Scania’s management with a requested date for start of production for the new product. During the configuration phase the assignment directive will be refined into a project definition (PDF), which can be seen as a quotation from the project management to Scania’s management that states that the project can be carried out with a certain amount of time, resources and cost. In the project definition the project management will promise a date for start of production of the new product.

Figure 14 - Continuous introduction process at Scania
Chapter 3 – Theoretical framework

During the configuration the milestones for the rest of the project will be set, there are 15 general milestones that are applicable to all projects that can be seen in Table 2. Some of the milestones in the table are written in bold text, these are major decision points for the project. Apart from the 15 general milestones each sub-project will have to make their own time schedule with necessary milestones. The sub-project time schedules will be merged to the master time schedule of the entire project; this is done during a SPP workshop. SPP is short for Scania Project Planning, which is a method for planning projects within Scania at all levels, in all contexts (Scania CV AB, 2011). It gives a method for planning the project by breaking down milestones to activities, and setting necessary times for all activities. As well as project planning, the method also supports project management by using the project plan.

Table 2 - General milestones in continuous introduction

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project kickoff</td>
</tr>
<tr>
<td>2</td>
<td>Product Performance target</td>
</tr>
<tr>
<td>3</td>
<td>Cost weight and other targets</td>
</tr>
<tr>
<td>4</td>
<td><strong>Project definition approved</strong></td>
</tr>
<tr>
<td>5</td>
<td>Investment decision taken</td>
</tr>
<tr>
<td>6</td>
<td><strong>Product performance approved</strong></td>
</tr>
<tr>
<td>7</td>
<td>Service market products</td>
</tr>
<tr>
<td>8</td>
<td>Project deviation decision</td>
</tr>
<tr>
<td>9</td>
<td><strong>Product verified</strong></td>
</tr>
<tr>
<td>10</td>
<td>Batch Closed SOP decision</td>
</tr>
<tr>
<td>11</td>
<td><strong>Repair and Maintenance (R&amp;M) cost approved</strong></td>
</tr>
<tr>
<td>12</td>
<td>Start of Sales-decision</td>
</tr>
<tr>
<td>13</td>
<td>Batch Closed SOCOP decision</td>
</tr>
<tr>
<td>14</td>
<td>Final product hand over to red arrow</td>
</tr>
<tr>
<td>15</td>
<td><strong>Project termination</strong></td>
</tr>
</tbody>
</table>
When the project definition and project time schedule is approved by the PQ meeting, an equivalent of the CQ meeting in the concept development process, the configuration phase is completed and the project moves into the development phase. Now the project is proceeding according to the project plan defined in the configuration phase. The actual product is developed using cross functional work with all the departments that are involved, and the performance of the product shall be verified (Jarnulf, 2012). The progress of the projects is reported to a weekly pulse meeting where project managers, as well as representatives for different departments attend. The status of the projects is visualized using green, yellow, red, white and black color markings. The different colors represent the following statements (Jarnulf, 2012):

- **Green** – We have no deviations, work is proceeding according to plan.
- **Yellow** – We have identified an imminent risk of a deviation, or we have a deviation but we have an action plan to solve it.
- **Red** – We have a real deviation and we don’t have an action plan to solve it.
- **White** – We have no deliverables in this project.
- **Black** – We have deliverables in this project but no resources are allocated to it.

The step between development and process verification and market prepare phases is determined by the outcome in milestone 9 in Table 2 – product verified. This is an acknowledgement that the developed product fulfills the demands that are set in the product definition. The purpose of the process verification and market prepare is to make sure that all departments are ready to release the new product to the market, including production, purchasing, sales and after market. It is in this phase that the product starts being delivered to customers. Shortly after start of customer ordered production the project will be closed and the responsibility for closing any remaining issues will be handed over to the next phase in the PD process – product follow up.
3.4.3 Product follow up (red arrow)

The product follow up phase maintains and updates the current Scania product range. The phase consists of four different assignment types that are introduced continuously throughout the year (Scania CV AB, 2011):

1. Field quality – quality issues that have been experienced by customers or discovered by Scania production units or service workshops.
2. Product change request – change requests from different stakeholders within Scania, for example production.
3. Design adjustments – continuous product improvements that are initiated by the responsible design departments.
4. Cost reduction – This is a cost rationalization proposal; they often require design changes, verification and risk analysis.

In turn the field quality (FQ) assignments are classified as quick, medium and heavy depending on their complexity and lead time (Scania CV AB, 2011), this has been visualized in Figure 15.

![Figure 15 - Classification of assignments in product follow up process.](image)

The objective of the quick assignment is to find a short term solution for the problem within 24 hours and to define a permanent solution within 10 days. If a permanent solution is not found within 10 days, the assignment will be changed to a medium or heavy assignment. Medium assignments are normally handled by dedicated competencies and resources, while heavy assignments require expert resources and considerable verification (Scania CV AB, 2011).
4 RESULT FROM CASE STUDY

This chapter comprises the results of the case study and has three sections, one for each participating company. The information gathered in this chapter is based on interviews with employees at Scania, Sandvik Coromant and Atlas Copco Rock Drills, and internal company documents and instructions. In this study references will not be given for specific quotes made by individuals, but all interview participants will be listed in the references chapter.

4.1 Scania

Scania is a global truck and bus manufacturer. Sales and service organization is spread in over 100 countries, while production units are located in Europe and Latin America (Scania CV AB, 2011). Scania’s head office is based in Södertälje, Sweden, as well as production units, Research and Development and a central purchasing department. Scania has approximately 37,500 employees worldwide, and almost 9000 of all employees are working in Södertälje. In 2011 Scania reached a company record in production output, with almost 84000 vehicles.

4.1.1 Organization and Roles

Scania is built like a line organization, where functions like R&D, Production and logistics, Purchasing, franchise and factory sales are working in parallel. R&D and Production and Logistics departments are mainly divided in three parts: Powertrain, Chassis and Cabs and support functions. Each competence area is divided by different product groups as well as by component manufacturing or assembly. An example can be seen in Figure 16.

The organization in the process development projects will comprise of members from different functions of Scania, including R&D, production, component manufacturing, assembly plants. For each PD project there will be an overhead project leader, as well as a number of object leaders. The role of the object leader is similar to that of a sub-project leader, as they are responsible for a sub-system in the PD project. If the PD project is a new engine platform for example, then an object leader could be responsible for the crank system and parts included, such as crankshaft, connecting rod, cylinder liners. Another responsibility for an object leader could be the engine body, including parts like cylinder block and cylinder heads. The role of the object leader is to plan and coordinate activities between R&D and other stakeholders such as production and purchasing for all components that they are responsible for. This responsibility is constant, even outside the typical PD project the object leader shall coordinate the information flow between R&D, production and purchasing continuously. The operative development work is carried out by design engineers and test engineers that are responsible for one or a few products.
In the engine component manufacturing plant there are two engineering roles connected to each product; (1) a process planner, who is responsible for the manufacturing process, including programs, fixtures and tools. (2) An industrial engineer who is responsible for layout, manufacturing and handling equipment, safety and working environment. There are also a number of support functions within each production unit that will be influenced by a PD project such as measuring room, material and production planning and maintenance. At the engine component manufacturing plant the process planner will normally be the local project leader, since the introduction of a new process will mainly influence the manufacturing process. In the case that the responsibility of the industrial engineer is influenced, they will also be involved.

A common opinion among the process planners was that the roles and responsibilities of the process planner and industrial engineer was sometimes a little bit unclear, or at least the expectations on the two roles from other people in the organization. A common perception within the engine production is that all matter related to PD projects and introduction of new products fall within the responsibilities of the process planner, even typical tasks for an industrial engineer such as purchasing new lifting equipment.

4.1.2 Meeting forums
The meeting forums that are held at a company level such as weekly pulse meetings, CQ and PQ meetings have already been described in paragraph 3.4.

Since the object leaders are responsible for coordinating activities between different functions within the company they have a cross-functional meeting forum called object meeting. The object leader has one object meeting for each of the products they are responsible for. The meetings are held regularly, but the interval is decided by necessity and can vary from every week to once a month. The purpose of the meeting is to gather all stakeholders related to a product and coordinate all activities in PD projects within the continuous introduction process. Design, component manufacturing, assembly and purchasing are always invited to the meeting, and when it is necessary other stakeholders like service and aftermarket are also invited. The object meeting is the most important cross functional meeting forum that is defined in Scania’s PD process.

Object leaders at Scania feel that there is a good participation from production at the object meetings; however there is a risk that the meetings change from coordinating activities to technical discussions about specific issues, which is not the purpose of the meeting. Such meetings should be held between process planner and designer according to the object leaders. Both process planners and designers at Scania feel that the object meeting is a good forum for coordinating activities and having discussions about technical issues, for example to review drawings or test results. Some process planners have a feeling that the purpose of the object meeting is a bit unclear, as well as the expectations on the participants of the meetings. The design department sees a potential for improvement in how the engine production demands certain information from the designers. As an example they could state that they need drawings of a certain status “there and then” to be able to perform a certain task on time.

Apart from the object meetings the information exchange between process planners and designers can be characterized as an informal dialogue. The roles and responsibilities between process planner and designers are clear, and there is no organizational barrier to take personal contact to discuss any issue with the design or prototype manufacturing or other tests. Informal contacts are held by necessity, using telephone, e-mail or meeting in person. For some products telephone contact is held daily, while others are more seldom. The general perception is that the informal contact methods work very well
between production and design. Within this interface there can be design reviews held, but the process of design reviews and the demand for them is not specified in the PD process. Therefore the initiation of the design review can sometimes come from designers, and sometimes from process planners, depending on when someone feels that there is a need to review any design change.

Since the process planners are acting as local project leaders for the introduction of new products in the engine manufacturing plant they are also responsible for informing other stakeholders, such as industrial engineers, the production line, logistics and material planning, of the progress in the PD projects. The method for spreading information about PD projects varies from process planner to process planner. One process planner uses a forum called “local management team”, it is a weekly meeting held by the production supervisor for a line. The ones that are invited are process planner, industrial engineer, operator team leaders and quality coordinators. The meeting was originally meant to be used to coordinate and plan continuous improvement activities on the production line, but it can also be used to discuss quality issues and PD projects. Another process planner has a “product meeting” together with operator team leaders and quality coordinator, that focuses on quality issues with the product, test runs that should be made in the production line and PD related activities. On a third line, the production supervisor has a daily quality pulse meeting with a few focus areas, and PD activities are one of them. On a fourth line the process planner is responsible for holding a PD and Quality meeting, where production supervisor, operator team leader and quality coordinators are participating. It is used to plan and follow up issues connected to product development projects and in line quality. This line is a little bit special since the manufacturing of the product is divided in two different departments, where one department do all the soft machining and hardening, and the next one do all the hard machining and finishing. The divided departments place higher demands on coordination.

Most of the process planners feel that they do not have a perfect way to coordinate activities with the production line and spread information. Some of the process planners even feel that it can be very difficult to be allowed time in the production line to make prototypes or other test runs. There is an internal routine for reserving time in the production line to produce a prototype batch of products or make some other job on a machine, for example preventive maintenance. A form is sent to the production planning unit at least 4 weeks in advance with proper motivation and explanation, and the production planning should make room in the production schedule for the process planner to run their prototype batch. Some of the process planners have tried to use this method, but the common opinion is that it is not really working; the requested time is seldom reserved in production. Other process planners usually take the request directly to the production supervisor and skip the production planner.

4.1.3 Standardized working methods

In the past few years there has been a sort of generation change within the process planner staff at Scania, more than half of the process planners at the engine manufacturing plant have less than 2 years experience. When asked about their activities in the PD process they found it hard to describe what must be done. They felt that there were no good description of what should be done and when. The more experienced process planners on the other hand could give a brief description, but mainly referred to MPP as a tool for planning their activities in a PD project. At the engine manufacturing plant in Södertälje a checklist has been developed based on the activities stated in written description of the MPP work model. The checklist has been used as a planning tool for the introduction of new products within the engine manufacturing plant. The less experienced process planners on the other hand felt that the written description in the MPP work model were a little bit to general to really
support an inexperienced process planner. Some desired a better description of how certain tasks should be performed in the process.

One method to support the process planners that has been developed parallel with this master thesis is the development of standardized milestones in the PD process for both assembly workshops and component manufacturing. These milestones shall supplement the 15 general milestones that are applicable for all projects, listed in Table 2. The milestones are visualized on three different levels in Figure 17. The top level consists of the 15 general milestones previously mentioned in paragraph 3.4. On the middle level are the 14 milestones that are set by all assembly workshops (axle and gearbox assembly, engine assembly and Chassis assembly) to highlight their most important events in the PD projects. On the bottom level is the first draft of the eight milestones that should be applicable to all component manufacturing workshops (engine components, transmission components).

The milestones that have been defined for the assembly workshops are listed in Table 3. They put a lot of focus on the need for iterative test assemblies and preparing material flow to the assembly lines. Other milestones focus on the global coordination between different assembly workshops. GPP stands for Global product preparation, which is a process, aimed at having the same assembly process in all Scania workshops globally. Another important milestone is P12, when the product structure should be prepared in MONA which is the assembly production support system, where the product structure is translated to assembly instructions, material needs. An effort has been made to clarify when some of the milestones must be finished, using the key activity SOP – Start of production, as a reference.
Table 3 - Assembly workshop PD milestones at Scania

| P1   | P and L / R and D agreed          |
| P2   | Test demand                      |
| P3   | Input for financial calculations set |
| P4   | Production target in PDF         |
| P5   | Development test assembly        |
| P6   | Performance test assembly        |
| P7   | Plan for introduction, ramp-up and phase out agreed (SOP -180) |
| P8   | GPP preparation initiated, ECO 3:4 (SOP -120 days) |
| P9   | Verified test assembly           |
| P10  | GPP preparation ready (SOP -55 days) |
| P11  | Logistic pulse initiated         |
| P12  | Line preparation ready in MONA (SOP -40 days) |
| P13  | First serial home (SOP -25 days) |
| P14  | SOP-production                   |

The milestones of the component manufacturing are a bit different in character than the ones for assembly workshops; they are listed in table 4. For assembly workshops the main issues are to plan for prototype assemblies to verify the relationship between different parts in the assembly process. For the component manufacturing the key issue that defines the size of the whole PD project is whether or not the components can be manufactured in the existing production structure, and if not, what types of investments need to be made? As a way to emphasize the lead times of machine investments the first milestone has actually been placed already during the concept development. That is a clear statement from the component manufacturing workshops that they must be involved that early in the PD projects to be able to put requirements on the new products and investigate the need for investments. The milestone has to be finished before the concept review (CR-1), as the result of the milestone gives valuable input to the approval or rejection of the concept. The milestones are iterative by nature, as is the MPP, as the process plan is done in iterations as the product is being developed. The final milestone in the table has also been clarified with a date when it has to be finished, and it is connected to the SOP – Start of production, which is the activity when the production process should be verified.
Table 4 - Component manufacturing PD milestones at Scania

| M-1. (CR-1) | Foundry and Manufacturing requirements described  
|             | Volumes and ramp-up identified  
|             | Investments and casting/manufacturing cost identified  
|             | Lead-times identified  
|             | Need of test casting/prototype manufacturing Identified  
| M1.         | Effect on “0-0-85-95” analyzed  
|             | Casting and manufacturing requirements agreed  
| M2.         | Volumes, production structure and ramp-up agreed  
|             | Investments and production cost up-dated  
|             | Lead-times up-dated  
| M3.         | MPP preparation initiated  
| M4.         | Design agreed for casting/manufacturing  
|             | Volumes, production structure and ramp-up defined  
|             | Investments and production cost defined  
| M5.         | Prototypes cast and manufactured  
| M6.         | MPP preparation ready  
| M7.         | PPAP approved (SOP -90 days)  

Another issue that has been raised during the interviews that is connected to the milestones of the component manufacturers is the way that requirements on the new products are being formulated at the start of a PD project. The main method of collecting data has been to gather the process planners that are currently working with a certain type of product and brainstorm demands based on experienced problems in the production. The result of this is that some of the requirements can be quite vague and unclear to the designers, such as the following example:

*Shape the product for easier cleaning/removal of chips*

The benefits of such demands may be quite easy to understand, but the way to fulfill the demands is unknown and it can only be verified by testing. Other demands will be clearer such as the following examples:

*Standardized holes and threads on the component*

*No threads of smaller dimension than M8*

These types of demands are clear and easy to understand, and it is very easy to verify that the demand has been fulfilled. A quite common opinion in the construction department is that requirements from engine production are not always backed up by facts. If a demand for a standardized dimension on threaded holes was followed by additional information such as the extra cost of having two different drilling and threading tools, it would be easier to make a trade-off between one and two dimensions. Another situation where further information could be added to the discussion is regarding tolerances. Setting the tolerances should be a trade-off between product performance and production cost, as tighter tolerances drive higher production costs. Additional information that could be used for deciding tolerances is the capability within the current process, and the extra cost of achieving higher tolerances, for example through investments in tools, fixtures or machines.
A third type of demand that has occurred in some projects is the demand that the design department shall perform a D-FMEA, a failure mode and effect analysis that focuses on the risks of deviations based on the design of the part. The output of the D-FMEA is supposed to be used as input when the process planners make their own P-FMEA that focuses on risks of deviations in the manufacturing process.

At Scania’s Axle- and gearbox assembly a lot of effort has been put in to defining their local PD process. Not only have they been instrumental in developing milestones for all assembly workshops, they have also come a long way in identifying their own activities that lead up to the milestones. Activities have been identified for four different roles that are all connected to the product development projects – PD coordinators, their local project leader, process planner and industrial engineers, logistics and material planning. In Figure 18 there are five different rows with different figures that represent different activities. The top row represents the PD coordinator, the second row consists of all the activities of the local project leader, the third row is for logistics and material planning, and the fourth row is for the process planner and industrial engineer. The fifth row is a mirror of the row for the local project leader, and it is used to follow up the status of the project and the product introduction in the assembly workshop in Latin America.

Figure 18 - PD process axle and gearbox assembly

The aim has been to define a PD process that is very comprehensive, and the result is that not all activities are applicable for all projects. During the configuration phase of a project the assembly workshop will go through the whole process and decide which activities are applicable for the specific project. The visual model is accompanied by a list of all the activities with related information. The list can be used as a toolbox for the project planning, see Figure 19.

Figure 19 - PD toolbox axle and gearbox assembly
4.2 Sandvik Coromant
Sandvik Coromant is a world-leading supplier of tools, tooling solutions and know-how to the metal cutting industry. Their focus is on increasing the productivity of their customers by innovation and development of new tools to continuously improve metal cutting methods. The company has 8000 employees worldwide and is represented in over 130 countries (Sandvik Coromant, 2012). This part of the case study has been performed at Sandvik Coromant with their R&D department in Sandviken and their production unit in Gimo.

4.2.1 Project model
Sandvik have developed a stage gate project model for their product development process. The model consists of three main phases – pre-study, project execution and evaluation and closure. The model has five major decision points (gates) that are critical for the progress of the project. The outcome of the decision point can be one of three things: (1) Go, (2) Kill or (3) revise project scope (step back). The gates are supplemented by milestones which mark smaller passages in the process.

At Sandvik they have three different project classes depending on the scope of the project:

A. Projects including new tool holders AND inserts
B. Projects including either new holders OR inserts
C. Projects that extend an existing family of products, either holders or inserts

Figure 20 - Product development process at Sandvik Coromant

The process model at Sandvik consist of five phases:

1. Pre-study
2. Development of product solution
3. Pre production
4. Production ramp-up
5. Evaluation and closure

The pre-study is characterized by cross-functional teamwork between the two main stakeholders at this point – design and production. Marketing and sales is the third main stakeholder, but they will not be involved until later, approximately 12 months before the release of new products. There are also a few support functions that are involved this early in the project, such as sourcing, purchasing and prototype workshop and test lab. The whole pre-study is based on the customer needs that are the driver of the new project. The scope of the project shall be determined – how many different
applications should be included in the project. A feasibility study is performed, and the production units that will manufacture the new products are decided, including an investment analysis within the different units. As the project proceeds into the next phase the new product will be designed and tested. The prototypes are manufactured and tested in Sandvik’s own facilities in Sandviken. Occasionally field tests will also be performed at customer’s plants. In the following phase – pre production – the product design will be finalized as well as the production investments. A pre-series will be manufactured to verify the production process. When the pre-production is finished the production ramp-up will start, stock will be built to be able to handle the demand immediately after a product is released. The market release point is called CoroPak (CP in Figure 20) and occurs twice yearly, in the spring and in the autumn. These are the only two occasions yearly that new Sandvik products may be released to market; hence several different new products will be released to market at the same time. After CoroPak release the project moves in to the final phase – evaluation and closure. In this phase the main focus is to document the project in order to learn from the experiences gathered throughout the project.

### 4.2.2 Organization and Roles

The R&D organization at Sandvik is divided in two departments depending on the type of machining the tools will be used for; Turning (rotating workpiece) and milling and drilling (rotating tools). Each product group is divided in four different competence areas that can be seen in Figure 21.

![Sandvik Coromant R&D organization](image)

For each product development project a project leader is assigned, and the project team of designers is selected from the organization depending on the scope of the project.

At the production unit in Gimo the tool holder and the inserts factory have different types of representation in the product development projects. At the tool holder factory there are dedicated project leaders for the introduction of new products. The local project leader has the responsibility to plan activities, time schedules, responsibilities and budget for the production side of the project. The project leader has a process planner and industrial engineer as available resources for the activities to be carried out. In the inserts factory on the other hand, they usually appoint a process planner as the local project leader for the introduction of new products. The process planner has the same responsibilities for the product development project as the project leader at the tool holder plant, but he/she is also responsible for supporting and improving the current manufacturing process.
Chapter 4 – Result from case study

4.2.3 Meeting forums
At Sandvik there is no company level coordination meeting between different projects. The status of the projects including any deviations is only communicated to the steering committee using status reports. If the project leaders need any support from other projects due to deviations, they are depending on their individual contact with other project leaders in order to find support or extra resources.

On a project level it is up to the project leader to decide the scope and frequency of the meeting forums. A common way is to have weekly project pulse meetings with cross-functional participation. The project pulse meetings are used mainly to coordinate activities and follow the status of ongoing tasks. Due to the geographical distance between the design department in Sandviken and the production unit in Gimo (~110 km) pulse meetings are often held with the help of videoconferencing where participants can see each other and share documents on screen.

The project model also states a minimum requirement for the use of design reviews. The design department is responsible for the design review, but if the production department feels the need for extra discussions about the manufacturability of a product they can initiate design reviews as well. Meeting in person rather than using videoconferencing is a more common method for this type of meeting.

4.2.4 Standardized working methods
At Sandvik there is a set of mandatory milestones defined in the project model that are used in all projects. The mandatory milestones in the product development process are accompanied by a set of milestones developed in a product introduction process that is used at the production units. The product introduction process defines what activities must be carried out and when they need to be carried out. All the necessary steps in a product introduction are clarified as well as the previously mentioned milestones.

To further support the project leader in the product introduction Sandvik have a project management model, each phase of the project is defined and the responsibilities of the project leader is described phase by phase.

To support project planning Sandvik are trying to use standardized lead times for recurring activities in product development projects. The lead times have been estimated and are used as input to the project planning. However the use of standardized lead times has not been completely successful, as it happens quite regularly that the actual lead time exceeds the standardized lead time that was used for the project planning. A perception among some of the project leaders is that the problem is not simply that the standardized lead time is too short to finish the task on time. Sometimes the problem might be that the lead time is too long, and the performer of the task does not feel any pulse in the task, thus the work risks being carried out too slow or too late.
4.3 Atlas Copco Rock Drills

Atlas Copco Rock Drills AB is a part of the Atlas Copco Groups business area called Construction and Mining Technique. The company has 1900 employees and is mainly located in Örebro (Atlas Copco Rock Drills, 2012) and the business includes product development and manufacturing of surface drilling and underground excavation equipment as well as spare part distribution to its customers worldwide. Atlas Copco Rock Drills will henceforth be called Atlas Copco in this thesis report. Even though the core business for Atlas Copco is within the Rocktec department – manufacturing and assembly of rock drills – the biggest part of their business is development and assembly of large excavation equipment such as drill rigs, underground loaders and mine trucks. This part of the case study has been performed at Atlas Copco Underground Rock Excavation in Örebro and focuses on their development of new underground excavation machines and the project model that is developed for that purpose.

4.3.1 Project manual

Atlas Copco has developed a project manual for all their PD projects, to maintain a standardized way of performing projects. The main project manual has in turn been slightly adapted to fit different divisions within Atlas Copco, including Underground Rock Excavation in Örebro. The project manual includes three classes of projects depending on the size of the project – Large, medium and small – and can be seen in Figure 22. The choice of project class is decided by using a standard template where the risks of the project are weighted against the success factors in areas such as final product quality, final product cost, project time, and project cost and market opportunity.

Figure 22 - Three different project classes at Atlas Copco
The project manual has five main phases, which can be seen in Figure 23 below:

1. Project preparation
2. Realization
3. Verification and validation
4. Industrialization
5. Follow up and close

Depending on the class of the project, the amount of sub phases varies, as larger projects require a more comprehensive process than smaller projects. Each sub phase is defined in the project manual with its general purpose, required input, activities to be performed and deliverables to subsequent phases. The project manual also contains project gates and milestones that must be passed to proceed in the project. The main difference between gates and milestones is that passing a gate must be approved by the project steering group, while passing a milestone is a decision taken within the project group. For each gate there is a checklist of necessary deliverables that must be fulfilled and approved by the steering group.

During the project preparation phase Atlas Copco perform a feasibility study and a concept study, the main objective of these studies is to answer two questions with a customer need as the starting point: (1) is the project feasible for Atlas Copco? (2) How can the needs of the customer be solved by a technical solution? During the phases all internal stakeholders have an opportunity to give input to the analysis of the questions. If the project preparation is approved the project will move in to the realization phase, more engineers are involved as the project work turns more cross functional. The machine is developed by the R&D department, resulting in a product structure and a BOM (Bill of materials) that is delivered to the production department. With the BOM as a starting point a rough assembly instruction is made, that will be the base for assembly of the prototype machine(s). The creation of the BOM and the assembly instructions are done iteratively by design and production in order to achieve a good product structure that will allow as simple assembly as possible.

When the product structure is approved, the prototype machine(s) are assembled. In the subsequent phases in verification and validation they are functionally tested as well as field tested. After tests are approved, a final review of the BOM and product structure is performed with feedback from the prototype assembly in order to prepare the machine for pre-series and serial production. This is performed in the industrialization phase where all parts are sourced on a higher level, i.e. larger...
modules are sourced instead of single components in order to simplify assembly. When the machine has been introduced to serial production the project moves in to the final phase – *follow up and close*. During these phases the R&D department is still integrated in the process to follow up the assembly of the machine, in case any further improvements can be made on the product to simplify assembly or improve the quality of the machine.

When the project moves from the project preparation phase to the realization phase a rough project plan will be made for all forthcoming phases and the detailed plan will be made only for the nearest phase.

### 4.3.2 Organization and Roles

The organization within Atlas Copco is built like a line organization, where different functions are parallel in the organization, such as production, purchasing, marketing and R&D. Within each function there are different departments that specialize in different areas of the function. Within R&D for example there are departments for product development, technology development, prototype building and validation, Continuous product improvement as well as a project office that are devoted to improving the Atlas Copco project model. The departments are also divided into subgroups depending on the specific product they are working with. In Figure 24 a part of the organization of the R&D department at Atlas Copco is illustrated with the different levels in the organization.

![Figure 24 - Part of organization chart R&D department at Atlas Copco](image)

Other functions at Atlas Copco such as production and purchasing are divided in a similar manner.

In the PD project organization there will be representatives from each function at Atlas Copco, as well as an overhead project manager. From each function there will be a devoted project manager who will select project team members from their line in the organization. As seen in Figure 24 for example, there is a group within the *product platforms* department called project office – consisting only of project managers. The other groups, divided by product segments, consist of designers and other engineers that will participate in different projects. An example of the project organization is seen in Figure 25 where some common examples of PD project members are illustrated. The Atlas Copco project manual provides a detailed description of the tasks, responsibilities and authorities for project participants in different levels, from steering group to project member.
Chapter 4 – Result from case study

The production unit at Atlas Copco has several representatives in the production sub-project group. First of all there is a dedicated project leader, who will coordinate all the activities in the group, but also represent the interests of the production units through the whole project. In the production sub-project group there are also production engineers, process planners and assembly personnel with responsibilities like ordering new lifting equipment and fixtures, making assembly instructions.

4.3.3 Meeting forums

At Atlas Copco there are several types of meeting forums used in the projects. On a company level there is a weekly project pulse meeting where all project leaders gather to get a snapshot of the status in all the projects. The meeting has two focus areas. First all sub-project leaders will have a chance to raise any issues regarding their resources in all projects. This is done by using color marking on a whiteboard with a matrix table. Each row represents one stakeholder and each column represents a project. Issues are visualized by red markings, and when there is no problem it is visualized by a green marking. This focus area will allow Atlas Copco to have a good coordination between projects to handle resource deviations. All resource owners also participate in this part of the meeting to handle the coordination in a good way without suboptimisation within the organization. The second focus area of the meeting is the general project status for different projects; here all main project leaders are responsible for visualizing the status of their projects in a few different categories such as overall status, cost and quality.

On a project level there are several meetings being held. The main project leader is responsible for having a weekly project meeting with all the sub-project leaders. The focus area of this meeting is mainly overhead coordinating between different activities and to make sure that there is a good way to handle any deviations that might come up. Sub-project leaders also have regular meetings with their project groups, but they are often characterized by a more technical focus, and could be called work-meetings rather than project meetings as specific technical issues are discussed and solved during these meetings.

One very important meeting forum that is demanded in the project model is a cross functional design review. The minimum demand is that before passing a gate in the model a design review should be held to get a cross functional agreement on the status of the design. Usually there are more frequent design reviews in the projects, especially during the realization phase, where the detailed design is done. During the planning of the project the need for design reviews are determined by the project group. The design reviews are then carried out in an iterative manner where all stakeholders can give feedback on the design based on their requirements placed in the early phases of the project.
Another important meeting forum that is used in a specific phase of the projects is called the build meeting. It is a cross functional meeting in the prototype workshop where prototype builders, designers and industrialization engineers are present to follow up the status of the prototype build and also to evaluate the status of the design. If any issues regarding assembly difficulties arise during the prototype build they can be handled by the build meeting and given a priority. The issue will then be solved by the designers of the product.

4.3.4 Standardized working methods

As project information and information management is a vital part of the project work at Atlas Copco, the project manual includes guidelines about key documents that must be used during the project and archived when the project is closed. The guidelines provide a number of documents that should be used to support the project managers in their work. The project class decides which documents are applicable to the specific project.

Some of these key documents that must be used are checklists for each gate, they include a number of general aspects that must be considered during the project, such as an overview of the business case of the project, and how it fits in Atlas Copco’s strategic plans. The checklists also include a number of deliverables to the project for different stakeholders, such as the main project leader and sub-project leaders for design, marketing, purchasing, and production and after market. This list of deliverables is used as support for the sub-project leaders to help them plan their activities in each phase of the project. A possible improvement that is being discussed at Atlas Copco is the possibility to distinguish the deliverables in two groups: mandatory and non-mandatory. This will help an inexperienced project leader to determine if there are some deliverables that might not be applicable for a certain project.

Atlas Copco is working on mapping their PD process one step further, in addition to the checklists which contain deliverables to the project, they are also working on mapping deliverables and dependencies between different stakeholders to further support the project leaders in planning their activities. The need for this is based in a recent organization change at Atlas Copco; a new group within research and development has been created called prototype and validation. Their responsibility is to plan and perform the build of the prototype machine(s) and plan and perform functional and field testing of the machine(s). Previously the prototype assembly was within the responsibility of the production units, and the testing was within the design department. This has created a set of new dependencies between design, prototype and validation and production in the product development projects. For example the design department creates the bill of material (BOM) for a new machine; the production unit will prepare the BOM in the production planning system and create rough assembly instructions as well as order the parts for the prototype machine. The prototype and validation group will in turn build the machine and give feedback on the design with focus on how easy it is to assemble of the machine. The mapping of cross-functional dependencies will result in a list of clearly defined activities, including who is responsible for carrying out the activity, who is the recipient, when it must be finished and if possible, how long it will take.
Chapter 5 – Analysis and discussion

5 ANALYSIS AND DISCUSSION

On a general level one can say that all three companies participating in the study have seen the importance of defining and visualizing their own PD processes. Both Scania and Sandvik have a quite low level of detail in their model in the sense that the phases and milestones are general and applicable for all stakeholders. The resemblance with the model described by (Johannesson, Persson, and Pettersson, 2004) is high regarding the main phases. Atlas Copco on the other hand have a little bit higher level of detail in the sense that there is a more clear ownership of the different phases, the design department has ownership of the early phases from pre-study to validation of the design, whereas production will take over ownership of the phases industrialization and follow-up and project termination. That being said, it is also clear that Atlas Copco’s project model resembles the model described by (Johannesson, Persson, and Pettersson, 2004), see Figure 5 - Model of the PD process described in literature the main difference is that the phases detailed engineering and production preparation have been expanded compared to Johannesson’s model.

One reason why Atlas Copco have been able to adopt a more detailed project model might be that their PD projects are externally driven by market demand or legislation, and are internally driven as a need project. Both (Johannesson, Persson, and Pettersson, 2004) and (Holmdahl, 2010) state that those types of projects are characterized by less uncertainty and more knowledge and experience is available within the company, thus planning and execution is easier compared to technologically driven projects for example. Both Scania and Sandvik are more prone to running projects with a wider set of drivers, including all external and internal drivers described in section 3.1.1 External drivers for product development and 3.1.2 Internal drivers for product development. The varying set of drivers that may apply on the PD projects at Scania and Sandvik may be the reason for keeping the PD project model more general, to be able to cope with varying conditions for the projects.

5.1 Clarification of the PD process

During the study it has become clear that the process planners at Scania need more support in their professional role as local project leader for the introduction of new products within the engine manufacturing plant. The MPP which is the standardized method currently used has not been adequately taught among the newer process planners. The process planners that have more experience of MPP feel that the method is time consuming and it is usually not requested to use the method and the associated check-lists, therefore it is used infrequently. When informed about the steps in MPP, some of the newer process planners feel that the method gives an adequate description of what needs to be done, but they are lacking more information about how these things should be carried out. It is a common understanding within the organization that there is a need to clarify the PD process for the engine manufacturing plant at Scania.

A comparison can be made with Atlas Copco, where the process has been clarified using two different tools. The first one is the checklists for each gate in the process model; the checklists support the sub-project leaders in planning their activities for each phase by defining a set of deliverables to the project for each gate. The next tool is a list of all deliverables between different stakeholders throughout the project. The creation of this list has given sub-project leaders from different departments an opportunity to raise demands on the actual process, and clarify when they need deliverables from other departments in order to deliver on time themselves. Another good case can be found within Scania, at the Axle- and gearbox assembly plant where an internal PD process has been created. A cross functional team with experienced engineers has mapped the process by defining all necessary activities that they need to perform, and also what activities or information that they require from other stakeholders.
This type of cross-functional work to identify activities and dependencies could provide great benefits for the engine manufacturing regarding clarifying the internal PD process. By using the milestones in the PD process set for component manufacturing plants combined with the main activities in the MPP method a first step could be to identify all the activities that need to be carried out within the engine manufacturing, and when they need to be carried out. Just by identifying all necessary activities will support the process planners in making an action plan and time schedule for all of their activities in a new PD project, it will give valuable information to the configuration phase of the PD projects. If the PD process for the engine manufacturing plant has been defined to the extent that the what and the when has been answered, four more steps can be carried out to further clarify the process:

1. The ownership of all activities within the engine manufacturing can be clarified further, and defined to different roles, such as PD coordinator, process planner, industrial engineer, production planning and production line. The clarification of the different roles and their responsibilities within the PD process will support the consolidation of different stakeholders around the actual project. For example by clarifying the necessary participation from production planners and the production line regarding prototype production the burden would be smaller on the process planner to make sure that prototypes are being produced.

2. The lead times for different activities within engine production can be defined, or at least estimated to further clarify the time that is necessary to perform the projects. It would give further valuable input to the project planning in the configuration phase. However it is important to remember that standardized lead times are difficult to follow, as seen at Sandvik Coromant. A good way can be to use a standardized lead time as a template when planning the project, but still taking the conditions and demands of the specific project in consideration, allowing a little bit of flexibility. Defining template lead times will also support the engine production in their desire to be involved as early as possible in the PD projects. One example could be in the case that a new product cannot be manufactured in existing production equipment; the lead time for investing in new machines must be communicated to the design department thus increasing the understanding why the production must be involved already during the concept design.

3. When all the activities that need to be performed in the engine manufacturing plant has been identified, as well as template lead times, it will be easier to clarify what type of activities and information the production unit is depending on getting from the design department. In addition to defining a set of dependencies, the required delivery times can also be set. This kind of information will further increase the understanding of the PD process within the engine production, as well as support the design department in prioritizing their own activities depending on when their deliveries are required. This can also be connected to the requirements that have been given by the engine production to certain projects. Sometimes the activity perform a design FMEA has been required in a project, but this type of activity should typically be specified in the required activities by design department set in the engine productions local PD process.
4. An additional clarification to the PD process is to create instructions to the activities that should be carried out. Some of the necessary activities are Scania standardized work methods, while others are rather vague. In many cases it is mainly a question of gathering information, as many activities have been explained in literature, but not made available to Scania engineers. Some examples are CPP that describes a step-by-step method for creating a process plan, FMEA which is a method for identifying risks with the design or manufacturing process, and ABC that provides a way of estimating production costs.

One specific issue that should be clarified in the local PD process of the engine production is the use of design reviews. Nihtilä (Nihtilä, 1999) states that it is one of the most important integrators between production and design department, where the design can be reviewed against the requirements set on the product in the beginning of the project. Both Atlas Copco and Sandvik have stated a demand in their project models for using design reviews. The participants have been defined and the minimum required frequency. At Scania however there is no defined requirement to use this type of meeting forum, this creates a risk, since the use of design reviews is depending on individuals and it might be overlooked due to lack of time or other reasons. That being said, all participants in the study felt that the use of design reviews was working quite good today, but the risk is still there.

One factor that differs between Scania and the other two companies, Sandvik Coromant and Atlas Copco is the possible variations in contact persons from project to project that can occur at the latter two. Sandvik Coromant and Atlas Copco have groups of designers that are responsible for a group of products, and a similar situation within the production units, there are a number of project leaders that are responsible for a number of different lines. At Scania the area of responsibility is smaller regarding the number of different products, there are only one or two designers with the main responsibility for one type of product, for example all crankshafts, or all connecting rods. At the same time the process planners are only responsible for the machining process of one type of product.

This situation at Scania is unique among these three companies in the sense that it gives superior possibilities to build informal integration between individuals, which is a key integrator between production and design according to Nihtilä (Nihtilä, 1999). Strong individual integrators reduce the organizational resistance for taking contact between different departments, and support a good dialogue between different stakeholders in a project. This is reflected by the common opinion between process planners and designers at Scania that there is a good climate for an open dialogue between the two departments, even though there isn’t really any clear demand for it in the process. At Sandvik Coromant and Atlas Copco there is a possibility that the designers assigned to a project with a certain type of product varies from time to time, and some people felt that it could be unclear who was responsible for a certain issue in some cases. On the other hand Sandvik Coromant and Atlas Copco have an advantage compared to Scania, that lies in a form of redundancy among the designers, as a larger responsibility and competence area is shared by many.

The effort to improve the participation of the engine production in product development projects will consume resources, as will the work to define the internal PD process of the engine production. This might be met by resistance by different roles within the organization at Scania since it will take time from their normal work supporting the production lines. This can be remedied in two ways, where one is a minimum requirement, and the other is a possibility to further improve the use of resources. The minimum requirement for focusing more effort on the PD process will come from the management of the engine production, it must be made clear that it is a high priority issue to increase the participation in product development projects through the entire organization. By giving a strong message to all stakeholders to increase priority on PD projects, a better participation can be achieved.
The second measure to address resistance to the increased workload is to give some additional thought to the different roles within the engine production. Anderson (Anderson, 2008) states that manufacturing engineers should be divided in categories with different focus areas, where some focus on the introduction of new products, and others on improving the manufacturing process and firefighting. A similar solution can be found at both Atlas Copco and Sandvik where they have local project leaders at the production units that are working full time with coordinating the participation of the production units in the product development projects. Another example can be seen within Scania; at the axle- and gearbox transmission plant, one engineer has been hired to work full-time with developing the local PD process. Regardless of which method Scania engine production chooses to use, a more clear distinction must be made between the effort that should be put in to supporting the production line, and working with introduction of new products.

5.2 Design and methodology of the study
The design of the study can be discussed regarding the selection of investigating three companies instead of just focusing on the internal process at Scania. If the study had focused only on Scania the result could have been a more developed solution in terms of defining the activities that are necessary within the local product development process within the engine production at Scania. On the other hand the investigation of three companies has given some valuable input to the analysis of the findings of the case study that have given extra depth to the discussions. The continued effort to define the PD process of Scania engine production could be carried out in a master’s thesis to follow up the conclusions of this study. The fact that three companies were investigated also increases the applicability of the conclusions due to the fact that they are a little bit more general, and slightly less Scania specific.

The literature study proved fruitful, there was a risk of low applicability of some sources since they comprise of secondary data, but that has not impacted the result of the study.

During the empirical study the choice of performing interviews with a rather low degree of standardization and structuring proved to be fruitful. Lots of useful information was found that could have been difficult to obtain if the interviews were more structured and more precise questions had been pre-defined. A disadvantage was experience with performing oral interviews, since the study was carried out by a lone author there was occasionally some difficulties in taking notes during the interviews, and some issues had to be clarified during follow-up phone calls that didn’t really add much more information. A remedy would have been to record the interviews, or start out with written interviews where the recipients had a chance to answer to the questions in written, and the author could have used oral interviews to follow-up and add more depth to the interview. Observations were mainly used at Scania, but they gave valuable input about the nature of different meeting forums. No major contradictions were found between the information found during interviews and observations.
6 CONCLUSION AND FUTURE WORK

The purpose of this master thesis is to investigate how a production unit can be integrated in the product development process as early as possible at Scania. The current situation at Scania shows a gap between the knowledge among process planners that is expected by the organization, and the knowledge that is available. The process planners are not to blame for this, but rather the organization that has not clarified the process and educated the employees.

6.1 Recommendations to Scania

The first step that Scania should take is to educate all process planners in the MPP method that is already well defined. That education will give all process planners a good picture of what type activities are required during the introduction of a new product. It will give additional benefits as the MPP is applicable to other issues than just new product introductions. Other roles within the engine production could also use an education in the MPP method to give a better understanding of the process. However this education could be slightly briefer as they do not need the same type of understanding as the process planner.

The second step that the engine production should take is to decide how resources should be allocated to developing the local PD process and participating in product development projects. The development of a local PD process must be a cross functional effort with participation from many different departments within the engine production. The responsibility for coordinating the cross functional effort however is best placed on a sole individual as shared responsibilities usually result in no one taking responsibility. This role has to be defined, either it could be placed on the PD coordinator or a new role as a process developer should be introduced. The decision that is taken in this issue will send an important message to the organization, as the PD coordinator will only be able to spend part-time on developing the process, whilst a process developer can work full-time. Introducing a new role of a process developer will clearly show that introduction of new products is important to the engine production, and it will be reflected in the rest of the organization.

The work to define the PD process of the engine production has a good starting point in the MPP method as well as the milestones that has been developed for component manufacturers; see the top two rows in Figure 26. The first step should be to align the phases and main activities in the MPP with the milestones set in the PD process, and based on them further activities can be defined, which would correspond with row three and four in Figure 26. As well as defining what activities should be performed and when it is also recommended to define ownership of all activities, estimated lead times for activities and defining required deliveries from design department. Creating instructions for different activities is also recommended, but it is slightly less important to do that at once since the impact of that effort is smaller than the previously mentioned issues.
6.2 Future work

During the study some issues have come up that are in need of further investigation but are outside the scope of this thesis. The issues could be investigated internally at Scania or they could be investigated as the scope of a thesis work.

The demands placed on component suppliers vary greatly depending on if the supplier is internal or external. For internal suppliers there is a method called Production Part Approval Process (PPAP) that is used to approve the internal manufacturing process for serial production. The workshop managers that are responsible for a production line will approve the manufacturing process of that line, in turn approving themselves as suppliers to the engine assembly plant. An external supplier on the other hand will also have to be approved using the PPAP method, however it shall be approved by a Scania sourcing manager. The workshop manager is in a position to be biased in his/her decision to approve a manufacturing process, and this situation requires further investigation to determine if it really is suitable.

Another issue that has been raised during the study is connected to the requirements that process planners place on new products at the start of PD projects. They are not always based on facts such as capability calculations of current production equipment. A study could be made to investigate the applicability of using statistical process control and capability measures as input to defining requirements on new products.

Sometimes process planners find themselves in a position where it is very difficult to find time in the production line to make a prototype batch of a new product. A possible solution could be to reserve a certain amount of capacity in each line for prototype batches and test series that should be available for the process planner. However it would not simply be enough to calculate for a certain amount of prototype parts to be produced when making a capacity plan, that reserved time must also be administrated and coordinated together with the normal production time. This issue should be investigated further at Scania.
REFERENCES


Chapter 7 - References


INTERVIEW PARTICIPANTS:

**Scania:**

Andersson, Bernt - Head of engine body design  
Andersson, Tobias - Process planner cylinder head  
Arnholm, Anders - Object leader engine body  
Basic, Samir - Process planner cylinder liner  
Carlsson, Matz - Process planner inline engine block  
Debord, Dominique - Designer valve system  
Jansson, Richard - Designer cylinder head  
Johansson, Kenneth - Object leader crank system  
Larsson, Annakarin - Designer connecting rods  
Larsson, Johan - Process planner cylinder head  
Larsson, Jonas - PD process developer axle and gearbox assembly  
Nilsson, Anton - Process planner V8 engine block  
Schalén, Henrik - Process planner camshaft and balance shaft  
Thorsell, Fredrik - Process planner crankshaft  
Wallenström, Mikael - Process planner connecting rod  
Väänänen, Pertti - Designer crankshaft and balance shaft

**Sandvik Coromant:**

Näslund, Jonas - Design Project leader  
Siivola, Wille - Production project leader  
Sjöberg, Tomas - Design Project leader

**Atlas Copco:**

Bratt, Sofia - Design project leader  
Hallemark, Peder - Group manager industrialization  
Hammarskiöld, Mattias - Group manager technical project office  
Håkansson, Peter - Prototype and validation project leader  
Magnusson, Niklas - Production project leader
APPENDIXES

Interview subjects for respondents within production departments

- Describe your role, responsibilities and the products you work with.
- Contact persons in design departments.
- Meeting forums (cross functional and internal production).
- Define and follow up requirements on new products.
- Is the PD process clarified – What to do? When? Deliver to whom?

Interview subjects for respondents within design departments

- Describe your role, responsibilities and the products you work with.
- Contact persons in production departments.
- Cross functional meeting forums.
- How do production define and follow up requirements on new products.
- Improvement potential within production units participation in PD projects.