Exploring the Value-Enabling Capabilities in Cross-Functional Product Development

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MASTER THESIS

Exploring the Value-Enabling Capabilities in Cross-Functional Product Development

A Study on the Engine Development Process at Scania

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Abstract

Purpose – Efficient product development is suggested as the new frontier of the manufacturing industry. This thesis investigates the value-enabling capabilities of stakeholders during product development at Scania. The purpose is to investigate their expectations of the process output and to identify factors which can have a critical effect on their fulfilment. Target areas are engine assembly and engine repair & maintenance.

Methodology – A qualitative approach was selected for the study, with an extensive data collection revolving around five key stakeholders, each bringing a unique perspective on the engine development process.

Results – Throughout the study, 22 stakeholder expectations were identified relating to the two target areas, each with a defined value. Seven influential factors, controllable by project team members, and eight contextual factors, setting the project conditions, were also identified. These factors can affect the value creation and the extent to which stakeholder expectations are met during the process.

Contribution – An understanding of stakeholders in the product development process is essential to benefit from their capabilities as value enablers and the results are intended to lay grounds for further research at Scania. Creating an awareness of expectations and the factors affecting their fulfilment can constitute a first step towards process improvement.

Conclusions and recommendations – Throughout the study, it was confirmed that the value-enabling capabilities of the stakeholders are not fully exploited and the phenomenon can be explained by e.g. attitudes, individual priorities, communication or time management. Taking a more including approach towards these stakeholders can, together with awareness of influential and contextual factors, contribute to higher quality of the new product development process output.

Keywords: Product development, cross-functionality, organisational learning, project management, lean

Sammanfattning

Syfte – Effektiv produktutveckling kan ses vara den nya fronten inom tillverkningsindustrin. Detta examensarbete utforskar intressenters värdeskapande förmågor under produktutvecklingsprocessen på Scania. Syftet är att undersöka deras förväntningar på processens slutleverans och att identifiera faktorer som kan ha en avgörande effekt på hur väl dessa uppfylls. Fokusområden för studien är motormontering och reparation & underhåll av motorer.

Metodik – För studien valdes ett kvalitativt tillvägagångssätt med en omfattande datainsamling som kretsade kring fem viktiga intressenter, där var och en tillför ett unikt perspektiv på motorutvecklingsprocessen.

Resultat – Via studien identifierades 22 stycken förväntningar kopplade till de två fokusområdena, alla med ett definierat värde. Sju inflytelserika faktorer som är påverkbara av projektmedlemmar och åtta kontextuella faktorer som sätter ramarna för projekt utkristalliserades också. Dessa faktorer kan påverka värdeskapandet och i vilken utsträckning som intressenternas förväntningar uppfylls genom processen.

Tillämpning – En förståelse för produktutvecklingsprocessens intressenter är avgörande för att kunna dra nytta av deras värdeskapande förmågor, och dessa resultat är avsedda att ligga till grund för vidare forskning på Scania. Att skapa en medvetenhet kring förväntningar och de faktorer som påverkar deras uppfyllandegrad, kan utgöra ett första steg mot en processförbättring.

Slutsatser och rekommendationer – Under studien bekräftades det att intressenternas värdeskapande förmågor inte alltid utnyttjas till fullo, ett fenomen som bland annat kan förklaras av attityder, individuella prioriteringar, kommunikation och tidsplanering. En mer inkluderande inställning gentemot dessa intressenter kan, tillsammans med en medvetenhet om inflytelserika och kontextuella faktorer, bidra till en högre kvalitet i produktutvecklingsprocessen.

Nyckelord: Produktutveckling, tvärfunktionalitet, organisatoriskt lärande, projektledning, lean

Acknowledgments

We gratefully acknowledge the support and generosity of our internal supervisors Anders Johansson and Mariam Nafisi, whom through their fields of research provided the opportunity for realising this Master thesis. Also thanks to our supervisor Damien Motte, associate professor at the division of Machine Design at Lund University, for providing guidance throughout the work with the thesis. You steered us in the right direction when needed and answered all of our questions, while consistently allowing for this thesis to be our own creation.

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Without you all, this study could not have been conducted.

Lund, June 2016

Karin Cederberg and Therese Enarson

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List of Acronyms and Abbreviations

AD	assignment directive
CD	concept development
CR-1	concept ready minus 1
DFA	design for assembly
DFS	design for service
F-gen	functional generation
FRAS	follow-up report administration system
IPV	in process verification
LCP	life cycle profit
LPD	lean product development
NPD	new product development
NPV	net present value
ODF	object definition
OL	organisational learning
PD	product development
PDf	project definition
PPM	product planning meeting
PRY-3	project ready minus three
PS	production system
R&M	repair and maintenance
SBCE	set-based concurrent engineering
SDP3	Scania diagnose & programmer 3
SES	Scania ergonomic standard
SPS	Scania production system
SRS	Scania retail system

V-gen	verification generation
VB	virtual build

Denominations of Scania's Functions and Departments

Here are presented all function and department denotations used throughout the report, to provide an easy overview for the reader. The organisational context of the functions and departments is further explained in two organisational charts in Appendix C.

DE	Engine assembly
DEP	Global industrial engineering
DEPA	PD project leaders
DEPB	Global product engineering
DEPG	Global product preparation and process engineering
DXT	Transmission machining
MP	Product introduction
MPPAP	Prototype assembly
MPPS	Project management
NM	Engine development
NMB	Engine development, base engine
NMBC	Engine body
NMBO	Lubrication System
NMBW	Valve Train
NMDC	Crank System
NMDF	Front End Accessory Systems
NMDV	Valve System
NMEO	Engine optimization Otto
NMGK	Intake Components

NMGV	Exhaust Components
P&L	Production and logistics
R&D	Research and development
TEEE	Industrial engineering experts
XP	Project office
XPB	Project management
YD	Technical product planning & vehicle validation
YDDM	Modularisation
YS	Vehicle service information
YSD	Method development workshop
YSNA	After treatment and fuel system methods
YSNB	Basic engine and components methods
YSR	Service products chassis, cab, body, maintenance

1 Introduction

This chapter aims to give an introduction to the thesis project: the background for the studied topic, the research questions and the scope of the thesis. The most important definitions used in the report are presented and lastly the outline of the report is described.

1.1 Background

In the competitive marketplace of today, understanding and serving customer needs quickly and accurately is key to survival for manufacturing companies. While there was traditionally a reliance on efficient manufacturing to provide customers with cost-efficient products, the market environment has shifted lately, leading to product development (PD) taking a far greater role in securing competitiveness (Morgan & Liker, 2006). Aligned with this transition is an increased interest in methods to improve the product development process, where a renowned candidate is lean product development (LPD), considered by McManus (2005) to leverage the creation of the right products and enable lean production.

Khan et al. (2013) defines the LPD process as a means to satisfy the needs and desires of all stakeholders. Identifying the stakeholders, i.e. those deriving value from the process, is the first step towards becoming lean and allows for defining value in a useful way so that value creating activities can be separated from waste (McManus, 2005). While some stakeholders are external to the PD process, recipients of the output, many functions of the company can also be utilised as value enablers during the process and provide useful insights throughout the stages of development. This cross-functional approach to PD is strongly advocated by lean practitioners as a means to adapt the product to the environment in which it will be produced, sold and used and it is demonstrated in success stories from the pioneering automotive manufacturer Toyota (Morgan & Liker, 2006).

While the most important source of new project ideas typically is the research and development (R&D) function, all functions within the organisation may provide unique insights (Turkulainen & Ketokivi, 2012). Given the constantly changing market environment of today, companies must actively work to allow new learnings to take place while also exploiting already embedded learning (Crossan, Lane, & White, 1999). By appreciating and exploiting value-enabling stakeholders during the PD process and by creating a learning environment which stimulates a dynamic knowledge basis, companies are thus believed to increase their competitive advantage.

Product development is one of the core processes of Scania (Scania CV AB, 2015d). A great range of company functions are involved during the development process and a rigorously standardised working process have been defined in order to encapsulate well-functioning routines. The company is greatly inspired by lean thinking, which is perhaps most apparent looking at their Scania Production System (SPS), and the new product development (NPD) process is governed by the three principles “customer first”, “respect for the individual” and “elimination of waste”. Although Scania performs well overall, with high market share and a strong brand as shown in Scania CV AB (2015a), the supervisors of this thesis, A. Johansson and M. Nafisi, have identified an improvement opportunity in the cross-functional working process during NPD. Johansson and Nafisi are both employed as industrial Ph.D. students and have, from their own experience of engine and cab production respectively, discovered there is still a tendency to regard some stakeholders as mainly external to the process, without benefiting from their full potential as value enablers. If so, the company fails to utilise the in-house competence as efficiently as it could.

Without a definition of, and an appreciation for, the value created by the process, improvement efforts cannot be guided (McManus, 2005). The starting-point of this thesis is thus to investigate stakeholders’ expectations of the output. Furthermore, the value creation of the NPD process will be examined; how cross-functional collaboration is conducted, how previous learnings are exploited and which mind-sets dominate the process. Two stakeholders will be targeted in particular, one related to engine assembly and one to engine repair and maintenance (R&M). As they are each involved in a subsequent process to the NPD process, they are of particular interest and the exploitation of their capabilities as value enablers will be investigated. Focus is on the working processes and how cross-functionality in the NPD process can contribute in the development of fresh, accurate customer offers strengthening the firm’s competitive advantage.

1.2 Purpose and Research Questions

The purpose of this Master thesis is to investigate external stakeholders’ expectations of the new product development process output, with the overall aim to highlight their value-enabling capabilities, and to identify factors which can have a critical effect on the ability of the process to meet these expectations. This can be summarised as the following research questions:

- Which expectations do external stakeholders have on the output of the new product development process and how do these expectations relate to value creation for the company as a whole?
- Which are the main critical factors affecting the extent to which external stakeholder expectations are met during new product development?

Focus is placed on including a variety of perspectives from within the organisation via extensive information gathering, to ensure comprehensive and reliable results.

Detailed guidelines for design are already present at Scania but in the knowledge of the authors and the internal supervisors, there is no compilation of stakeholders' expectations of the NPD process output formulated to emphasise the value they bring. Understanding stakeholder expectations and why their impact on the NPD process might vary is a step towards continuous improvement of the process, with the ultimate goal of increasing the quality and predictability of the output. This thesis will not cover all stakeholders nor provide a full solution to how a high and predictable quality of the NPD process output can be achieved. Expectations and critical factors will be identified, but how the awareness of them can change the studied process is not treated in this study. However, it is intended to lay grounds for further research to be conducted at Scania.

As the thesis was carried out at Scania Södertälje, the relevance of its contribution is evaluated in the eyes of the company, from a performance point of view. The identified problem was deemed important to Scania, since an efficient and value focused product development process lays the foundation for providing customers with advantageous product offers, thus crucial for the company's competitive advantage as declared in Scania CV AB (2010a):

> *"Scania is facing a future in which customers will increasingly seek transport solutions that guarantees industry-leading profitability throughout their lifetime. At the same time, the authorities are increasingly requiring more efficient transport, with less environmental impact. This demands greater competitiveness, which in turn means that we in R&D need to become more efficient and shorten time-to-market."*

1.3 Scope of Thesis

The thesis studies the process of new product development of engine components at Scania Södertälje. With new product development is meant development projects resulting in parts with new article numbers, hence not merely upgrades of the existing portfolio. All subsystems of the vehicle other than the engine, including the interface between the engine and the rest of the chassis are outside of the scope.

The NPD process will be studied from the point where the demand statement is initiated in the beginning of concept development (CD) up until the point when the product, in theory, is fully specified and no further design changes will be made.

With Scania terminology, that means the process is studied from the product planning meeting (PPM) until PRY-3, both process boundaries further explained in Section 2.3. This delimitation excludes the stages of verifying tests of the product and production ramp-up as well as any underlying research leading up to the identified opportunities initiating the NPD process.

While there is a multitude of stakeholders to the process, the scope is limited to two areas; engine assembly and engine repair and maintenance, both linked to a subsequent process to the one studied. Engine assembly was selected as both supervisors have experience from, and interest in, the assembly operations at Scania, one was even formerly employed at the function. Engine R&M was in turn selected as an interesting counterpart to assembly and because engine R&M is moving towards becoming a more integrated part of Scania rather than merely an external function, placing it in the focal point of the topic of study. The areas of engine assembly and engine R&M are at Scania represented by the functions of engine assembly (DE) and vehicle service information (YS) respectively, YS also being the voice of the service workshops in the NPD process as described in Table 1.1. Together with three additional functions responsible for design and project management (see Table 1.1) they make up the group of five key stakeholders of the NPD process targeted in this thesis. All key stakeholders are throughout the thesis considered as possessing value-enabling capabilities, able to provide input to the process and to take part in the NPD process activities. Two of them, DE and YS, are in addition also considered as external stakeholders to the studied process. This since a large part of their workload is related to processes subsequent to the NPD process, making them dependent on the output from the studied process as visualised in Figure 1.1.

Table 1.1 Targeted key stakeholders of the studied process. The external stakeholders are presented first, followed by the remaining three key stakeholders investigated in the thesis.

Key stakeholder	***Description***
Engine assembly (DE)	External stakeholder for the area “engine assembly”. Active before and after vehicle launch. Includes the in-house engine assembly lines.
Vehicle service information (YS)	External stakeholder for the area “engine R&M”. Active before and after vehicle launch. Represents and has contact with service workshops.
Engine development (NM)	Function of (among other things) engine design. Active during CD and PD projects up until vehicle launch.
Technical product planning & vehicle validation (YD)	Function of (among other things) project management. Active in CD projects, before vehicle launch.
Project office (XP)	Function of project management. Active during PD projects, up until vehicle launch.

Note: Department denotations are not acronyms of the full name.

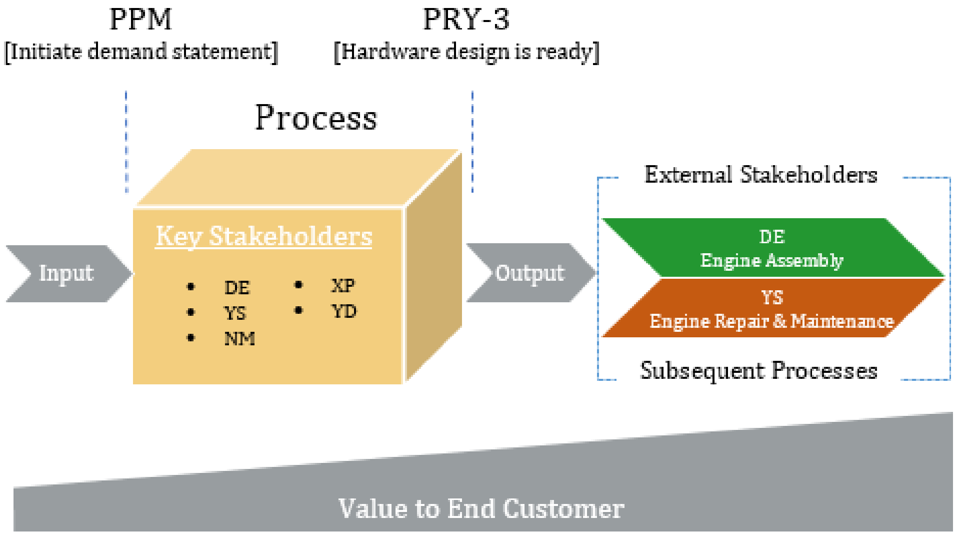

Figure 1.1 The scope of the study presenting the process boundaries and the classification of the studied key stakeholders. The value to end customer should increase throughout all activities performed.

1.4 Definitions

In this section, terminology relevant for understanding the report is explained. This consists of both company-specific Scania terminology and core concepts of the thesis, which are defined by the authors of this thesis and used throughout the report.

1.4.1 Scania Terminology

Table 1.2 Terminology used at Scania, including common abbreviations.

Term	*Description*
Assignment directive (AD)	Document containing the specifications for the project, including business case and targets, as they are set at the end of the CD process.
CATIA	Computer software used for generating 3D models and drawings of products and parts.
CD process	Concept development process. Begins with the identification of a demand and ends with a cross-functionally approved assignment directive.
Concept ready minus one (CR-1)	Milestone in the late stages of concept development, just before the concept is cross-functionally approved.
Concept review	Review session at R&D during the development process, connected to milestones in CD and PD projects. Ranges from CR-1 to final project hand over to red arrow (see Red arrow).
Design guidelines	Guidelines used by design engineers. Spreadsheet describing methods/actions to ensure that failure of a certain component or system will not occur in large scale. Continuously updated, e.g. by feedback from Lesson Learned (see Lesson Learned). Include design for assembly and SES (see Scania ergonomic standard), but not as main focus.
DFA checklist	Design for assembly checklist. An Excel file used to ensure assemblability, where both general and specific questions of the characteristics of the designed part is assessed, e.g. "Is the part designed so that an article number or other marking enables identification?". It also covers alignment with the assembly process, e.g. "Can the part be assembled without removing other parts?"
F-gen	Functional generation. Before V-gen (see V-gen). The number of the F-generation (F1, F2 etc.) indicates its placement in the sequence of F-generations, as the project moves through several ones before the final design freeze.
FRAS	Follow-up report administration system. Used for reporting and monitoring e.g. quality deviations. For example, product technicians can report problems with assemblability to an engineering design group. Deviations can also be reported from the ongoing production or even from the field.
Green arrow	One of three parts of the R&D process. At Scania, same as the "PD process". Headed by a project leader from XP.

Knowledge bank	Swedish: Kunskapsbanken. A wiki database with examples of designs well performed according to e.g. DFA.
Lesson Learned	Method used to avoid recurrent problems and to strengthen the learning in the organisation. Done by documenting the learning from earlier deviations. Before a deviation can be labelled as resolved, a Lesson Learned should be performed, where the root cause is identified and solutions described. Feedback is also shared about positive experiences, insights and methods, in form of listing success factors and improvement suggestions.
Life cycle profit (LCP)	Calculation of customer profit performed in both CD and PD projects to analyse the impact on the customer's profit from a vehicle when a change is implemented in the product structure.
Milestone	Describes an important happening or cross-functional interface in a project such as a performed activity, delivery or decision.
Object	A smaller but still cross-functional part of the project with a well-defined interface to other objects.
Object definition (ODF)	A break-down of the project definition to object level.
PD process	Product development process. At Scania, referring to new product development.
PPM	Product planning meeting. Cross-functional meeting at the beginning of the CD process.
Project definition (PDf)	Governing document of the project during the PD process containing e.g. targets for the product. A cross-functionally approved document written according to a strict template and updated as changes in decisions are made.
PRY-3	Project ready minus three. The time point in the process when no further hardware design changes shall be made.
Red arrow	One of three parts of the R&D process. Process for follow-up and improvements of products already launched.
Scania ergonomic standard (SES)	Document containing standards for ensuring ergonomics for employees, categorising each situation as green (OK), yellow (subject to improvements) or red (unacceptable). Two versions exist: SES Design and SES Production.
The Scania House	Scania's take on "the lean house", a visualisation of core values, principles and priorities as illustrated in Figure 2.1. Functional adaptations exist out of which "Scania production system" and the "R&D factory" are used in this report.
SDP3	Scania diagnose & programmer 3. A computer-based program that communicates with Scania vehicles, designed to support the mechanics. Used by workshops to troubleshoot, adjust customer parameters, make calibrations etcetera.

Takt time	During the development of a product, this is the time that the management has decided will apply. In production, this is the dedicated amount of time to each sequenced station at the assembly line to perform the assembly activities.
V-gen	Verifying generation. After the F-gens. Verifications are performed of parts, components or vehicle to ensure performance and property requirements or targets are met.
Virtual build (VB)	Sessions of a few hours where the engine is assembled virtually, step by step. Held every product generation during development by the product technician at the engine assembly function. These meetings are held around two weeks before each design freeze. Representatives from design, production and service are invited.
Yellow arrow	One of three parts of the development processes. Includes research, advanced engineering and concept development.

1.4.2 Definitions of Core Concepts

Table 1.3 Core concepts for this Master thesis.

Core concept	***Explanation***
Assemblability	The ease of assembling parts in a product.
Critical factors	Factors in the NPD process affecting to what extent external stakeholder expectations are met by the process output.
External stakeholder	Stakeholders active in processes sub-sequent to the studied, hence receivers and users of the process output. Identified external stakeholders treated in this thesis: DE and YS.
Key stakeholder	Stakeholders affecting the studied process to a great extent. Chosen key stakeholders treated in this thesis: NM, XP, YD, DE and YS.
Maintainability	The ease of maintaining a product.
Product introduction	Introduction of a product in the production system, in this study on the assembly line, before customer order production begins.
Reparability	The ease of repairing a product.
Requirements	Collection name for the input from key stakeholders to the studied process. It includes targets, demands, wishes and all other types of information sprung from their wants and needs.

1.5 Outline of the Thesis

After Chapter 1, presenting the context and scope of the thesis, follows an introduction of Scania in Chapter 2. The company and its philosophy are presented together with the CD and PD processes, which are the focal point of this study. The research design and detailed descriptions of each step are given in Chapter 3 and next, in Chapter 4, the theoretical basis for the thesis is provided covering the topics of lean product development, organisational learning (OL) and integration over functional interfaces. Findings related to the research questions are presented in Chapter 5 and further refined in Chapter 6, where the results of the thesis are provided under two sections; one for each research question. Finally, results are analysed and discussed in Chapter 7 leading up to Chapter 8 where conclusions are drawn and recommendations given. Additional information is also provided in four appendices.

2 Scania CV

This chapter gives an introduction to Scania, the automotive manufacturer studied in the thesis. After an overview of the company and their philosophy, their R&D process and more specifically the new product development process will be described in relation to the targeted key stakeholders.

2.1 Introduction to Scania CV

This year, 2016, Scania celebrates 125 years and has over time developed into one of the world's leading truck manufacturers. It is since 2008 majority-owned by Volkswagen AG (Scania CV AB, n.d.). Scania provides solutions in trucks, buses and coaches, engines and services such as workshop services and driver training. Additionally, Scania's sales and service organisations and finance companies are distributed worldwide. The network consists of 1600 workshops for sales and vehicle service meaning that when a customer visits Scania it is usually one of these rather than a production site (Scania CV AB, 2015a). On average, the vehicle needs to spend time in a workshop 4-16 times annually (Scania CV AB, 2014a).

Scania's global production system consists of ten production units in seven countries, located in Europe (Sweden, France, Netherlands, Finland, Poland) and Latin America (Mexico, Brazil). Eight regional product centres, mainly located in southeast Asia but also in Russia and South Africa, handle assembly, additions and local adaption of the vehicles. The vast majority of the R&D function is located in Södertälje together with the production facilities producing gearboxes, axles and engines. Cabs are produced in Oskarshamn and frames in Luleå, but the final chassis assembly is performed in Södertälje. (Scania CV AB, 2015a)

This Master thesis is written at the department of Global Industrial Development (TE), part of the Production and Logistics (P&L) organisation. The aim of TE is to consolidate and develop Scania's joint competence within industrial engineering and logistics, as well as development and coordination of related IT-systems. The department holds industrial expertise within machine and process engineering, industrial project management and logistics, and IT-coordination and development (Scania CV AB, 2015c). Furthermore, it includes the department of External Research and Cooperation (TER). Its mission is to support P&L with research and external cooperation and to influence the Swedish production engineering education and research and design structure (Scania CV AB, 2016). TER consists of six employees, mainly industrial Ph.D. students, and is where the internal supervisors to this thesis are employed. Organisational charts visualising the departments' placement in the organisational structure is found in Appendix C. Note that the denotations for functions and departments are not acronyms of their full names.

2.2 The Scania Philosophy

Scania seeks long-term relationships with profitable customers (Scania CV AB, 2015a). By delivering high-quality vehicles and services at the right time, the customer's profit and uptime (the time the vehicle is in operation and thus generates revenue) are maximised, which builds the basis for a profitable company (Scania CV AB, 2015a). The company works with continuous improvements where everything not supporting the value creation for the upcoming stages in the flow should be eliminated. A pre-requisite for this way of working is that a standardised way exists, so that a normal situation can be identified and serve as a basis for comparisons in order to maintain, challenge and improve the current situation. This normal situation is thus also continuously challenged and enhanced as deviations are identified and adjusted in order not to recur and negatively affect the quality of the operations. (Scania CV AB, 2010a)

There are four core processes at Scania – product development, sales, order-to-delivery and service delivery – all which are built upon three core values influencing the activities performed (Scania CV AB, 2015d). The values, "customer first", "respect for the individual" and "elimination of waste", further described below, are interlinked and should be jointly applied (Scania CV AB, 2010a). When following the principles, a high quality of the products is achieved through an efficient process. This working method was originated in the Scania production system and the same way of working has been adapted to sales and services as the Scania retail system (SRS) (Scania CV AB, 2014b). The corresponding approach for research and development is the concept R&D Factory, explaining the core values and principles guiding the R&D function during the development process (Scania CV AB, 2010a). While the pillars of SPS are improving the resource efficiency and optimizing flows in production, the SRS aims to improve the customer service and service flow, and the R&D function strives for efficiency in the development process, high quality and shorter time to the market. This philosophy and working method is also used within purchasing, financial services and administration. (Scania CV AB, 2015a) The core values permeate the entire corporate culture and influence its daily operations, and the conceptual model described above is seen in the Scania House presented in Figure 2.1.

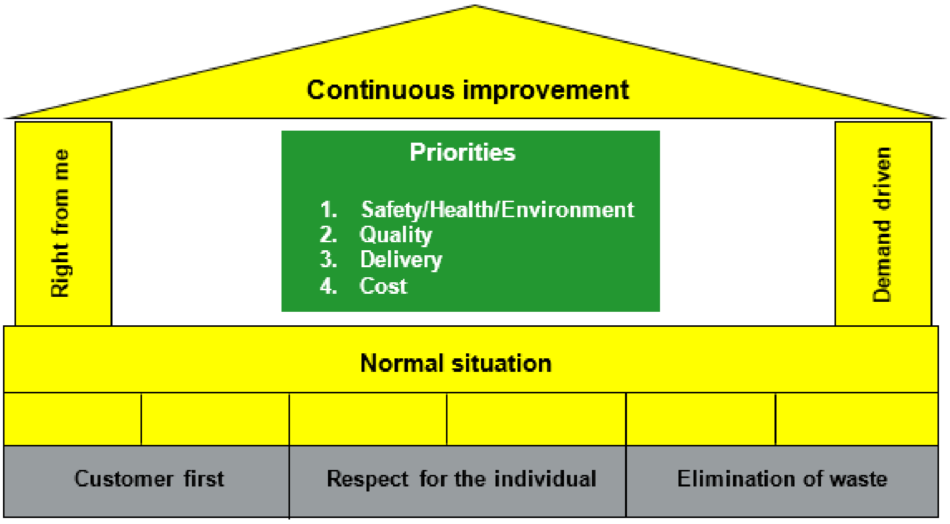

Figure 2.1 A generic interpretation of the Scania House by the authors.

"Customer first" means to have a good knowledge of customer's business and to put the operations and resource efficiency at the centre of the entire value chain, in order to deliver solutions enhancing the customer profitability. "Respect for the individual" describes the mind-set to recognise and capture all knowledge of the employees as well as the drivers of the vehicles. It also includes to let ideas and inspiration spring from daily operations in order to continuously improve. Finally, "Elimination of waste" aims at delivering high quality solutions where improvements are triggered by the needs of the customers but also by deviations from standards and targets. (Scania CV AB, 2015b)

"Right from me" means the agreements are kept between the senders and the receivers in the flow, hence between the previous, current and next stage in the process. If deviations are discovered, actions are taken to resolve them and feedback on quality is provided directly to the delivering party. Knowledge, tools, instructions and methods form the right conditions to do right, and the attitudes in the organisation should also be aligned with this. (Scania CV AB, 2010a)

"Demand driven" means the demand drives the flow. Deliveries are made when the next step in the chain demands so, which helps to avoid waste and supports the planning. Deviations are signalled when demand cannot be met and agreements are then drawn on how to resolve the resulting situations. This principle provides for a continuous feedback taking place. (Scania CV AB, 2010a)

The priorities help the organisation to focus on the right things and are all important as guidance to the activities. In abnormal situations where a compromise is needed, the order between the areas of priority help to steer the actions performed. Hence, only when a trade-off is necessary and priorities conflict with each other, is the safety/health/environment given the most weight, followed by quality, delivery and finally cost. (Scania CV AB, 2010a)

2.3 The Scania Research and Development Process

The R&D process at Scania is divided into three major parts: concept development, product development and product follow-up, as illustrated in Figure 2.2. Development of products, production or technologies are also supported by research and advanced engineering. Concept development begins with the identification of a market opportunity and includes planning and conceptual design while product development includes detailed design, most of the testing and production ramp-up. The CD and PD processes, further described in the following sections 2.3.1 and 2.3.2, together constitute the NPD process at Scania.

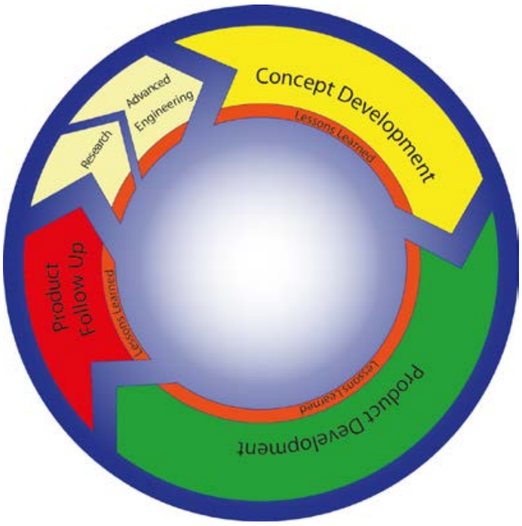

Figure 2.2 An illustration of the R&D process at Scania consisting of the yellow arrow (which includes research and advanced engineering), the green arrow and the red arrow process. Picture retrieved from (Scania CV AB, 2013).

Out of the five key stakeholders targeted in the thesis, technical product planning & vehicle validation (YD) is most active during CD and the project office (XP) during the PD, both within project management. Engine development (NM) is active throughout the both processes, responsible for engine design among other things. The functions engine assembly (DE) and vehicle service information (YS) represent the areas of engine assembly and engine repair and maintenance. These are active during CD but activities are often concentrated to PD and their level of involvement during both processes depends on the project. The main responsibilities of the key stakeholders are listed in Table 2.1 and further described in the following sections.

Table 2.1 Key stakeholders of the study and their responsibilities during CD and PD.

Key stakeholder	***Responsibilities include***
Engine assembly (DE)	Assemblability assessment and engine testing (CD and PD), product introduction on assembly line (PD) and engine assembly (sub-sequent process)
Vehicle service information (YS)	R&M assessment of solutions (CD and PD), service methods development, link to service workshops
Engine development (NM)	Engine design and testing (CD and PD)
Technical product planning & vehicle validation (YD)	Concept development project management
Project office (XP)	Product development project management

2.3.1 **Yellow Arrow: Concept Development**

Concept development projects always begin with an identified need, which in some cases comes from customer demand but can also be motivated by other main drivers, such as cost reduction requirements, technological advances or legal requirements (Scania CV AB, 2013). Once a reason for project initiation is identified by a function at Scania, a demand statement is formulated and presented at a PPM which is held regularly and is attended by representatives from all the R&D departments, commercial departments, purchasing and production (Jarnulf, 2015). Should the proposal be approved by the meeting, the first stage is to form a project team for further refining the business case and the conceptual proposition. The concept is then further developed in a swim lane process during CD configuration and a concept development phase as seen in Figure 2.3, resulting in a finished concept specified in an assignment directive (AD). The AD contains targets regarding technical properties, production, R&M costs and product cost as well as the business case behind the concept (Söderlund, 2015). At the end of the CD process, the concept should be so well defined that the remaining risks are small enough to ensure a high probability of the project to go through the green arrow according to plan. The target is that nine out of ten projects should reach start of customer order production at the planned date (Å. Andersson, trainer internal course “PD intro”, personal communication, March 21, 2016). To ensure cross-functional risk elimination, the CD process includes developing a concept for production, a sourcing strategy for critical parts, a definition of product layout and main interfaces, a prediction for property target fulfilment and early calculations of life cycle profit (LCP) and net present value (NPV). Thus, projects involve several functions already in the early stages, although the need for active participation depends on the extent to which each function is affected. (Scania CV AB, 2013)

During concept development, all major risks with the project should be identified and quantified so that only feasible projects progress to the following PD process.

The CD process is thus similar to a classic stage-gate process where there are a number of Go/Kill decision points. A stage-gate process design ensures unfavourable projects are terminated before too much resources are spent on them and the stage-gates also doubles as quality checkpoints (Cooper, 2008).

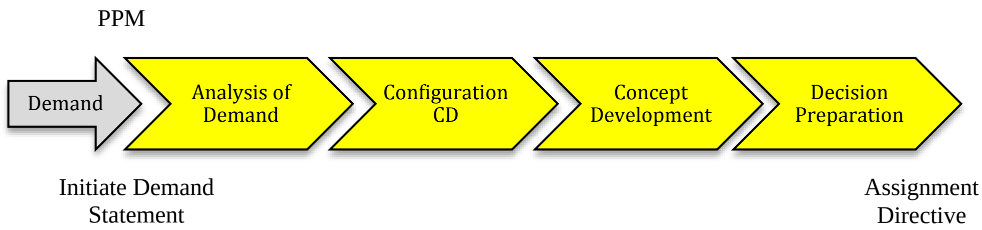

Figure 2.3 The CD process begins with an initiate demand statement and results in an AD, after which the project moves on to the PD process commonly called "the green arrow". Picture recreated from (Scania CV AB, 2013).

2.3.2 **Green Arrow: Product Development**

"Once we get to green arrow, then everybody shall be included."

(Å. Andersson, trainer internal course "PD intro", personal communication, March 21, 2016)

While the CD process is usually carried out by smaller, fast-moving teams the number of involved functions and individuals increases considerably in the green arrow PD process. It begins with a PD configuration phase where each function individually performs a risk analysis to determine the feasibility of the project. As one requirement of moving from CD to PD is that the project is plannable, the configuration stage also includes scheduling and resource allocation. The outcome of all PD configuration tasks are summarised in a project definition (PDf), the ruling and cross-functionally approved document which replaces the AD in the green arrow and is updated regularly to respond to changes during the project. During development, the product moves through several generations, which are iterations of the design, each ending with a design freeze where specifications for that generation are fixed. The last generation is called the verification generation (V-gen). Just before the V-gen, the milestone PRY-3 is found, which is a boundary of the scope of this thesis. At this stage, the hardware design is complete, enough tests have been conducted to indicate product life length and the deviation status is good enough for the project to be considered mature to move into final verification (Stål, 2016).

A project leader from the XP function is responsible for project management and cross-functional collaboration during the course of the project. In the PD configuration phase, projects are however broken down to cross-functional objects of more manageable size (H. Henriksson, product introduction method and process developer, personal communication, April 25, 2016). Objects are most easily described as sub-projects, each led by an object manager and defined by an object definition (ODF), and are typically defined based on which component or technology they deliver to the project.

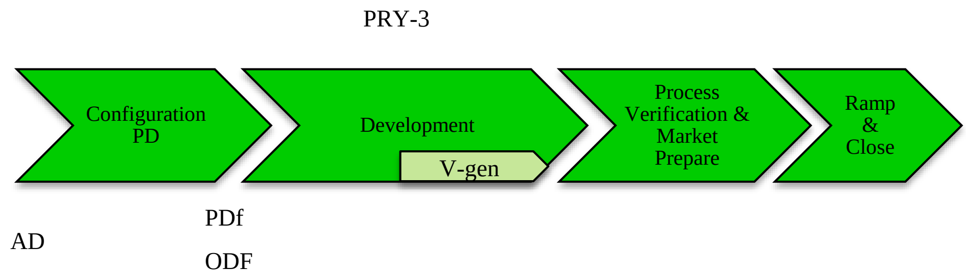

Figure 2.4 The PD process begins with a configuration phase after which the AD is replaced with PDf and ODFs. At PRY-3, in the development phase, the V-gen begins where the product design is verified. PRY-3 marks the end of the scope of this thesis. Picture recreated from (Scania CV AB, 2010b).

The engine development function (NM), is responsible for engine design and work in close collaboration with other R&D functions responsible for simulation, testing and for drawing up technical information.

For the engine assembly function (DE), the responsibilities during projects include reviewing design proposals from a production point of view, performing physical test assemblies, preparing the assembly line for the new introduction and educating the staff when needed (Scania CV AB, 2012). Their involvement in projects can begin already in the early CD process but the workload is typically concentrated to the later stages of the PD process.

The workload during the new development process for the function of vehicle service information (YS) is concentrated towards the end, when service methods, standard times for jobs and workshop information are produced. Still, their responsibilities also include evaluation of reparability and maintainability in the earlier phases. Targets for R&M costs and to some extent methods are already developed during the CD process. (Scania CV AB, 2014a)

The project is driven by parallel sets of milestones, some specific for functions and some on a cross-functional level. Milestones are checkpoints, decision points or quality gates (Scania CV AB, 2010b). Unlike the CD process, the PD process does not have a Go/Kill decision at the decision points as, if the process has been well-functioning, all risks leading to a kill in the late stages should have been eliminated.

3 Method

Here is presented the overall research design for the study together with more detailed descriptions of each stage – both theory on selected methods and implementation. While the research design framework was developed by the authors, the methods making up the framework are well-established which gave the possibility to use theoretical guidelines as the starting-point for the stages of both data collection, data processing and corroboration.

3.1 Research Design

With the authors being new to the company, thus not acquainted with the process to be studied, the initial phase of the research was an explorative pre-study aiming to give insight into activities and stakeholders of the NPD process at Scania. It served as a means to understand the current state and the challenges experienced by the employees, but also to create a network of stakeholders for further collaboration. In connection to this, in-depth theoretical knowledge on relevant topics was gained through a literature study.

In order to understand the stakeholders and the process, an extensive amount of raw data was collected using interviews, focus groups and participant observation. These are all common information gathering methods in qualitative research when the aim is to develop a deeper understanding of a subject (Bryman, 2011). Documented material, both generic and project specific, was also used as a source of information. Findings of particular interest to the investigation was extracted from the collected material for further processing, followed by a stage of data corroboration. That led to the formulation of results connected to the two research questions, so that conclusions could finally be drawn and recommendations given. The outline of the research is presented in Figure 3.1 and the detailed design of each stage will be presented in this chapter.

Although the methodology is built around the selected key stakeholders, which are all functions within the company, the end customers of Scania will be considered throughout the study using second-hand information. This is to ensure results and recommendations are not contradicting the preferences of the end customers, those who ultimately determine the success of the company.

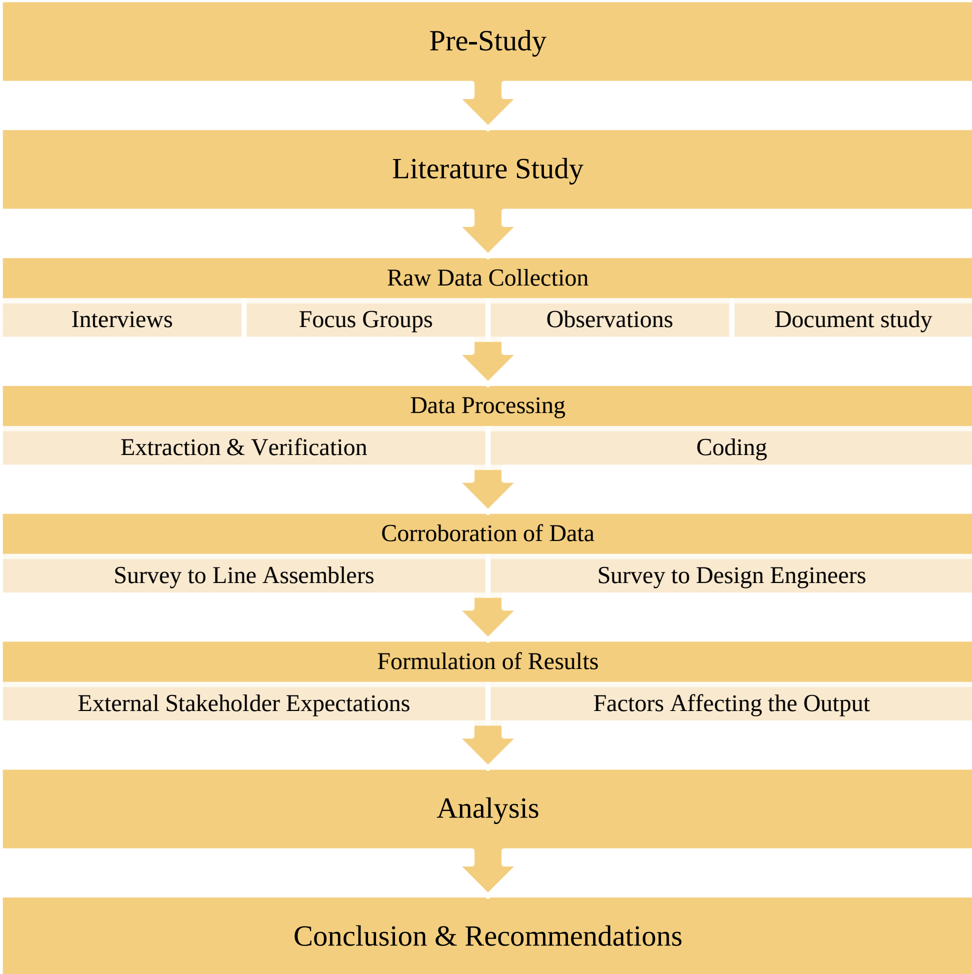

Figure 3.1 The research design.

3.2 Pre-Study

The first stage of the research was a pre-study aiming to further define the scope and to select the key stakeholders to be targeted, the identification of key stakeholders being a pre-requisite for process improvement (McManus, 2005). In this phase, the research questions were re-formulated in collaboration with the supervisors at Scania as feasible ideas were tested and the research problem narrowed down. Valuable input about the scope and the research approach was also received through discussions with a Ph.D. student at the company.

During the course of three weeks, five interviews were conducted in parallel with careful studies of internal documentation, in order to gain as much knowledge possible about the company structure, the overall NPD process and potential areas to target. The interviewees were selected based on experience of the Scania NPD process in general and not solely on engine development, as the scope was not yet clearly defined. Interview guides were developed for each interview to provide some guidance although the discussion was allowed to evolve freely. Examples of interview questions are provided in Appendix D.1.

The authors of this thesis were both present during the interview sessions to ensure that the data was assimilated by more than one person. The interviews provided an understanding of the challenges Scania employees are facing in their daily work and which improvement initiatives have already been started in some areas. They were also helpful in the process of identifying a suitable research problem and limitations. Furthermore, the interviews served as a channel to facilitate the access to key people related to the selected area of research. The interviewees during the pre-study are presented in Table 3.1 and their place in the organisational structure can be seen in Appendix C. To offer anonymity, interviewees are not presented with names.

Table 3.1 Targeted departments during the pre-study.

Department	***Responsibility or experience of interviewee***
Product Introduction (MP)	Method development of the product introduction process, chassis and cab
Prototype Assembly (MPPAP)	Digital and physical test assembly coordination, chassis and cab
Transmission Machining, Engineering (DXT)	Pre-production manufacturing engineering, transmission machining. Previous experience from product introduction, engine assembly (DEPB)
PD Project Leaders (DEPA)	Project management for product introductions, engine assembly
Project Management (MPPS)	Project management, chassis assembly

Note: Department denotations are not acronyms of the full name.

Upon finalisation of the pre-study, key stakeholders and external stakeholders had been identified and the boundaries of the process to be studied had been decided upon.

3.3 Literature Study

The literature study was performed in order to substantiate and further develop the research questions (Yin, 2009). This by studying general theory and current research on topics related to the scope. As most of the methods in the research design are heavily dependent on information retrieved from Scania employees, the literature study was also performed to reach beyond that and put the findings in a broader context to back up the results, analysis and recommendations to the company.

For each topic of study, two methods of finding sources of information were used: keyword search to identify the most relevant contributors within the field followed by snow-balling. The database used was LUBsearch, a resource provided by the Lund University libraries. To ensure validity of the references, only books and peer-reviewed papers were selected. When certain publications were not accessible via LUBsearch the scientific database Google Scholar was used.

The topics selected for the literature study are lean product development, organisational learning and interface integration in the product development process, including methods for integration.

3.3.1 Lean Product Development

A keyword search on "lean product development" yielded 1476 peer-reviewed results. Hence, to quickly scan the field, peer-reviewed review papers were used as starting-point for the study. The reference lists were soon found to converge towards a group of four researchers; J.M. Morgan, J.K. Liker, A.C. Ward and D.K. Sobek II. As they are all commonly cited contributors within the field and authors of numerous publications, their work was the main source of theory on lean product development in this thesis. Review papers were also used to place their research in a broader context and reduce the bias.

3.3.2 Organisational Learning

A search using "organisational learning" resulted in 49,855 peer-reviewed results from a wide variety of fields. To narrow down the number of hits, OL was used as a keyword in combination with lean product development, value stream mapping, new product development and value, all potential subjects to substantiate the problem formulation. Snow-balling provided an overview of influential contributors and also made for quality assurance. The paper by Schulze et al. (2013) came to serve as a synthesis of adjacent fields of theory since it provided an approach including all beforehand mentioned subjects. Also, the lack of a shared understanding of OL was addressed. Crossan et al. (1999) were investigated since several articles cited the authors and their framework.

3.3.3 Methods for Interface Integration

The search using "product development interface" resulted in 8549 peer-reviewed hits covering a wide range of fields. Several attempts to narrow down the search were undertaken, where finally the keyword search "R&D interface" yielded 4284 peer-reviewed results in LUBsearch, out of which one was an editorial viewpoint presenting four reviewed articles. The authors, T. Lager and J-P. Rennard, were deemed as renowned in the field, especially Lager who has published 19 peer-reviewed papers appearing at LUBsearch. The viewpoint thus provided the starting-point for snow-balling to find additional papers and contributors to the field.

3.3.3.1 Design for Assembly

A keyword search for "design for assembly" yielded 2085 result, out of which 118 book or e-books, indicating general acceptance of the term. Peer-reviewed review articles on design for assembly (DFA), e.g. Shetty and Ali (2015), pointed towards three major methodologies: the Lucas DFA Methodology, the Hitachi Assemblability Evaluation Method and the Boothroyd Dewhurst System. Since many recently published articles on the subject discuss applications of one or more of these rather than further development of their principles, the starting-point for the literature study was books and e-books describing these three major methodologies.

3.3.3.2 Design for Service

"Design for service" (DFS) showed to be unusable as a search word, as the results list was dominated by articles on services in other senses than R&M. "'Design for service' vehicle", "'design for service' engine", "design for repair" and "design for maintenance" also proved inefficient as keywords. The most successful was instead "design for disassembly" with 300 search results covering the area of interest, although most of them aimed towards disassembly of products at end-of-life. Theory on design for service was thus obtained by extracting relevant information from peer-reviewed research papers on design for disassembly.

3.4 Raw Data Collection

The raw data collection formed the basis of the research, laying ground for further investigations. It aimed to gather enough information about the topic from a sufficient number of sources for the researches to gain a comprehensive understanding of the engine development process at Scania and the selected key stakeholders. This rich data was collected using a variety of qualitative methods: semi-structured interviews, focus groups and participant observation. Using multiple methods reduced the risk of not covering all aspects of stakeholder interests and enabled exploiting the relative advantages of each method while reducing the negative influence of their respective disadvantages, as listed in Table 3.2. Told data was supported with information from internal company documents and archived project documentation as a means to reduce the risk of misinterpretation, inaccuracies and bias.

Taking a qualitative approach is recommended when in-depth understanding is required and suitable when linkages between events and activities is of interest, making it appropriate for this study (Bryman, 1992). The close contact with the subjects of research is time-consuming but will likely give a perception of the current state which corresponds better to reality than had more impersonal data collection methods been used.

Table 3.2 Critical review of data collection methods for stakeholder expectations, including both general and study-specific aspects.

	Advantages	***Disadvantages***
Focus groups	Interactions between participants can be studied (Stewart, Shamdasani, & Rook, 2007) Direct contact with respondents (Stewart et al., 2007) Less time-consuming than individual interviews (Stewart et al., 2007) Participants are experts in the area[a]	Risk that a few participants influence the others (Stewart et al., 2007) Limited generalisability of result (Stewart et al., 2007) Scheduling difficulties[a]
Semi-structured interviews	Highly efficient way to gather rich empirical data (Eisenhardt & Graebner, 2007) Information or hints of information can immediately be followed up The interviewee is an expert in the area[a]	Risk of data being biased by impression management and retrospective sensemaking (Eisenhardt & Graebner, 2007) Reflexivity (Yin, 2009) The semi-structured format makes interviews harder to compare than structured
Participant observation	Real-time data collection (Yin, 2009) Studies unconscious actions among subjects (for covert observation) Insightful (Yin, 2009)	Time-consuming (Yin, 2009) The short time allowed for observation might bias the data (Yin, 2009) With participation, there is a risk for manipulation of events (Yin, 2009) Lack of researcher experience in the studied area might lead to misinterpretation of events[a]

[a] Study-specific aspects with described research design

3.4.1 Semi-Structured Interviews

Interviews are highly efficient when aiming to gather rich, empirical data (Eisenhardt & Graebner, 2007). Therefore, interviews were held with representatives for all key stakeholders. The purpose was to, from as many perspectives as possible, discuss the involvement and opinions of the respective stakeholder during the NPD process. This in order to ultimately gain a comprehensive understanding of underlying activities, strengths and discrepancies of the process. The chosen interview format was semi-structured interviews, each with an individual interview guide consisting of primarily open-ended questions. Fact-based questions were alternated with more subjective ones regarding thought or perceptions of the interviewee. Taking an open-ended, semi-structured approach allowed for the interview to take unexpected turns based on the responses, making it useful for exploratory studies (Höst, Regnell, & Runeson, 2006). With an interview guide to fall back on, the general direction and topics were still maintained. The interview guides were unique but followed the same basic pattern, presented in Appendix D.2, to ensure the same topics were covered.

While there are many advantages with interviews, there is also a risk for biased data. To mitigate this risk, Eisenhardt and Graebner (2007) recommend using numerous and highly knowledgeable informants providing diverse perspectives of the same phenomena, wherefore the data collection included interviewees from different organisational levels and targeted a variety of competences, as seen in Table 3.3.

Table 3.3 Targeted departments for interviews during the raw data collection.

Department	***Responsibility or experience of interviewee***
Modularisation (YDMM)	Project management, CD projects
Global Industrial Engineering (DEP)	Head of DEP, engine assembly
Basic Engine and Components Methods (YSNB)	Development Engineer, service methods
Service Products Chassis, Cab, Body, Maintenance (YSR)	Manager for Maintenance Program
Project Management (XPB)	Project management, PD projects
Project Management (XPB)	Project management, PD projects
Engine Development, Base Engine (NMB)	Head of NMB; engine design, analysis and testing
Engine Optimization Otto (NMEO)	Engineering design, Otto engines
Industrial Engineering Experts (TEEE)	Global industrial engineering development. Previous experience from YS

Note: Department denotations are not acronyms of the full name.

A total of nine interviews were conducted, each lasting approximately one hour. All interviews but three were held by both authors, where one was more liable for taking notes while the other focused on the proceeding of the meeting. Directly afterwards, the content was summarised and the meeting minutes documented. All sessions were also recorded in order to facilitate the analysis work if situations would arise where the recording would be needed to clarify passages in the written material.

3.4.2 Focus Groups

Two focus groups were held as complement to the individual interviews, with the purpose of inspiring participants to deeper discussions about the engine development process and projects so as to enrich the data collection. The aim was to, for each of the two external stakeholder groups, answer the following questions:

- Which are the expectations and wishes of the external stakeholder regarding the output of the engine development process?
- How does the external stakeholder perceive the CD and PD processes and their own role in the projects?

Treating external stakeholders separately mitigated the risk of them not fully expressing their opinion out of consideration of other present parties.

Focus groups were selected as being a powerful method for exploratory research and less time consuming than conducting individual interviews with the same number of people (Stewart et al., 2007). The format of a focus group allows both for gathering of information from the participants but also for a deepened level of consciousness about their own perspectives through discussions with each other. Moreover, the interaction between the participants can be observed by the focus group moderators together with the participants' attitudes and responses to each other's ideas (Stewart et al., 2007). Although the goal was to collect a maximum amount of data, Bryman (2011) argues that large focus groups tend to lower the engagement of each individual resulting in the outcome not being necessarily better. Stewart et al. (2007) recommends a group size of six to twelve participants, with a slight over-recruit to compensate for late drop-outs, and Bryman (2011) reports of group sizes of down to four participants wherefore it was decided to keep groups relatively small. That however made the sessions more sensitive to late drop-outs and increased the importance of encouraging attendance.

The entire sessions were recorded and brief notes taken to document non-verbal information such as attitudes and atmosphere. Having a PowerPoint presentation projected for all participants to see it allowed for displaying the questions, presented in Appendix D.3 and D.4, one by one as they were discussed and allowed the discussion to stay on track. The level of moderator involvement was low during the discussions, limited to reading each question aloud to the group and asking for further development of interesting opinions or exemplification when participants formulated themselves vaguely.

3.4.2.1 Engine Assembly

The engine assembly focus group discussed assemblability and assemblability assurance of engines. An interview guide was developed in accordance with guidelines from Stewart et al. (2007) and care was taken to formulate each question open enough to invite every participant to answer. To stimulate the thoughts of the participants, the set of questions targeted the issue from different angles; free associations to the word assemblability, good and poor examples from their own experience, characteristics of a hypothetical perfect engine and reflections on their own contribution in creating end customer value. The first half of the focus group was conducted as a group discussion while the second half mainly consisted of a group exercise where the participants were given the task to write attributes of the product or NPD process affecting the ease of how they themselves or other functions can perform their job. This exercise aimed to stimulate discussions on cross-functional aspects of the NPD process and reveal information about the relations between company functions. Altogether, the session was two hours long and the full interview guide is provided in Appendix D.3.

Four Scania employees participated in the engine assembly focus group; three of them representing departments within the engine assembly function (DE) and a fourth participant with experience from both engine assembly and concept development, see Table 3.4. The composition was decided in collaboration with the internal supervisors to include different personalities and cover both concept and product development.

Table 3.4 Participant list for the engine assembly focus group.

Department	***Responsibility of participant***
PD Project Leaders (DEPA)	Project management for product introductions, engine assembly
Global Product Engineering (DEPB)	Product introductions and bridge between production and design, engine assembly
Global Product Preparation and Process Engineering (DEPG)	Product introduction and process preparation, engine assembly
Modularisation (YDMM)	Project management, CD projects

Note: Department denotations are not acronyms of the full name.

An invitation was sent out to all participants one week in advance, explaining the purpose of the session and their importance for the data collection stage of the thesis. The interview guide was reviewed by a process engineer at the engine assembly function to confirm formulations were clear and yielded useful responses. The session itself was conducted and documented as explained in Section 3.4.2. The reason no line assemblers were included in the group was that the presence of organisational barriers was not known in advance making it uncertain whether their participation could affect the willingness of the participants to speak freely during the session. Assemblers were thus treated separately during the observation part (Section 3.4.3.1) and the survey part (Section 3.6.2) of the study.

3.4.2.2 Engine Repair and Maintenance

The interview guide for the engine R&M focus group was largely an analogous version of the guide for the engine assembly focus group, presented in Appendix D.4. Instead of assemblability, the focus here was reparability and maintainability of engines. Using similar interview guides for both focus groups made for easier comparison of expressed attitudes and which topics were spontaneously brought up. It also allowed for a comparison of which projects were mentioned as well-functioning, as well as examples of projects where the external stakeholders had experienced problems in the cross-functional NPD process.

However, one major difference in the design of this focus group compared to the one about engine assembly was that the exercise in the second half was excluded, resulting in the session being only one hour. The reasons were the participants' busy schedules and that the exercise did not yield a significant amount of new results when conducted in the engine assembly focus group.

Four Scania employees with different responsibilities within engine or vehicle service were invited to participate, as listed in Table 3.5. The selection was primarily based on recommendations from managers and employees at the vehicle service information function but also the ability of the employees to attend at an agreed upon time. Although the group was small, participants came from widely different departments, so the captured perspectives included everything from practical service jobs to long-term strategic decisions related to vehicle service. The session was conducted and documented as described in Section 3.4.2.

Table 3.5 Participant list for the engine repair and maintenance focus group.

Department	***Responsibility of participant***
Method Development Workshop (YSD)	Complete vehicle mechanic
After Treatment and Fuel System Methods (YSNA)	Service method development, after treatment and fuel systems
Basic Engine and Components Methods (YSNB)	Service method development, basic engine and components
Service Products Chassis, Cab, Body, Maintenance (YSR)	Manager for Maintenance Program

Note: Department denotations are not acronyms of the full name.

3.4.3 Observations

As the aim of the data collection was to get a deep understanding of the studied process, areas of particular interest were also studied through observations. During observation, information is collected by observing the objects to be studied, watching what they do and how they behave, and the method is acknowledged to yield insightful data (Yin, 2009). The method of participant observation, where the researchers becomes part of the studied group, was selected for practical reasons. In participant observations, the role of the researcher can vary between complete participant to complete observer, differing by the degree of researcher participation in the activities. It can be either covert or overt, both types used in this study. For covert observation, the presence of the researcher and purpose of the study are not stated thus researcher's interference is minimal (McLeod, 2015). During overt observation, the researcher's presence is announced and the studied group are aware of the purpose of the study (McLeod, 2015).

3.4.3.1 Assembly Line Practice

A two-day practice period on the straight engine assembly line at Scania allowed for the authors to extend their consciousness to include hands-on assembly jobs. The purpose was to capture the perspective of assemblers and get a sense of the reality on the assembly line, instead of relying upon told data. As all assemblers in the area were informed about the presence of the authors and the overall purpose of the study, the line practice falls into the category of overt observation.

To make the most of the opportunity, information was collected through dialogue with assemblers, silent observation and by participation in assembly operations. Most information was obtained from two assemblers selected by the line managers as coaches and the dialogue revolved around the operations performed during the observation, the assemblability of the engines, the work environment and the assembly process as a whole. It should be stressed that while participation is considered an insightful method to understand a situation, see e.g. Yin (2009), the authors' lack of experience of engine assembly is a potential error source in the interpretation of events or activities. During the line practice period, notes were taken to document the observations and experiences when possibility was given.

3.4.3.2 Visit to Hovsjö workshop

Hovsjö workshop is a full vehicle workshop located close to Scania Södertälje, organisationally a regional office within BU Sweden. As opposed to the on-site workshops it mainly serves end customers and performs both surveillance before delivery of sold vehicles and service jobs during vehicle lifetime (M. Sundqvist, personal communication, April 5, 2016). The aim was to deepen the understanding of repair and maintenance of Scania vehicles, focusing on engines. The two-hour visit was a combination of an unstructured interview with a foreman and observation of service jobs performed by the mechanics. The level of participation of the authors during observation was low so as not to interfere with the work of the mechanics.

No interview guide was developed due to the unstructured nature of the visit, but the conversation was steered towards the topics of reparability and maintainability of engines, the role of mechanics during product development and improvement areas of the NPD process. For practical reasons, the session was not recorded but notes were taken by both authors and combined soon afterwards.

3.4.3.3 Meetings

Cross-functional meetings are a central part of the collaboration during the projects, thus regarded critical events to study in order to develop a comprehensive understanding of how functions collaborate and how cross-functional decisions are made. Observations were conducted of two such meetings of different character – one product planning meeting in the initiating stage of concept development (see Figure 2.3) and one Virtual Build (VB) meeting in the early development stage of the PD process (see Figure 2.4), where a design proposal in digital form is evaluated by representatives from several involved functions.

The PPM observation was conducted as a covert observation, resulting in minimal interference with other attendants thus minimal influence on their words and actions. During the VB meeting, the attendance of the authors was announced although the purpose of the study was never clearly specified. The role of complete observers was taken during both meetings, so no questions were asked until afterwards.

Both meetings were observed for approximately one hour. Notes were taken during the meetings and re-written as meeting minutes soon afterwards.

3.4.4 Documented Material

Data can be categorised as told data, reported data and executed data, depending on how it is provided (Bramklev, 2009). With interviews and focus groups aiming towards told data and observations towards executed data, i.e. activities performed, studies of documented internal material aimed to extend the data collection to include reported data. A list of the documents studied is provided in Table 3.6.

General information on the process and functions served, together with templates for project documents and descriptions of milestones, the purpose of verifying told facts and gaining increased knowledge of topics raised during interviewees. Documented material was in turn verified through told material, to assure its accuracy. A couple of documents and internal websites were also studied to review the tools and guidelines used or available for usage in the development process.

The opportunity was also given to study archived information from two ongoing projects, the selection being based on timing and diversity. Both projects were in relatively late stages, one just before and one just after process verification (see Figure 2.4), meaning the design was verified and the production process prepared. One project was described as successful from a project management perspective while the other was associated with difficulties, making them interesting to study in pair. Examination of archived project information allowed for the authors to see how templates are used, which information is documented and in what form, as well as which types of deviations from the normal situation can occur during projects.

Table 3.6 Documented information studied during raw data collection.

Type of information	***Source of information***
General process information	Scania governing documents
	Process charts
	Descriptions of process milestones
	Descriptions of function responsibilities
	Templates for demand statement, assignment directive and project definition
	Descriptions of the CD and PD processes
	General targets and requirements of the vehicle service information function
Tools and Guidelines	Knowledge bank [a]
	DFA checklist
	Scania ergonomic standard: SES Design and SES Production [a]
Project specific information	Assignment directive [a]
	Project definition (including targets) [a]
	Project plan
	Object definitions [a]
	Lesson Learned [a]
	Deviation reports from FRAS [a]
Material provided by internal supervisors	Previous project on engine assemblability

[a] Further described in Section 1.4.1 Scania Terminology.

3.5 Raw Data Processing

The stage of raw data processing is where the collected data is extracted from its original context and put together again in different arrangements, allowing for researchers to identify patterns in the great amount of available material and lift it to a more interpretive level so that conclusions can be drawn (Dalen, 2008). In this study, the data processing was performed in three stages; extraction, verification and coding, as seen in Figure 3.2 and further described in the following sections.

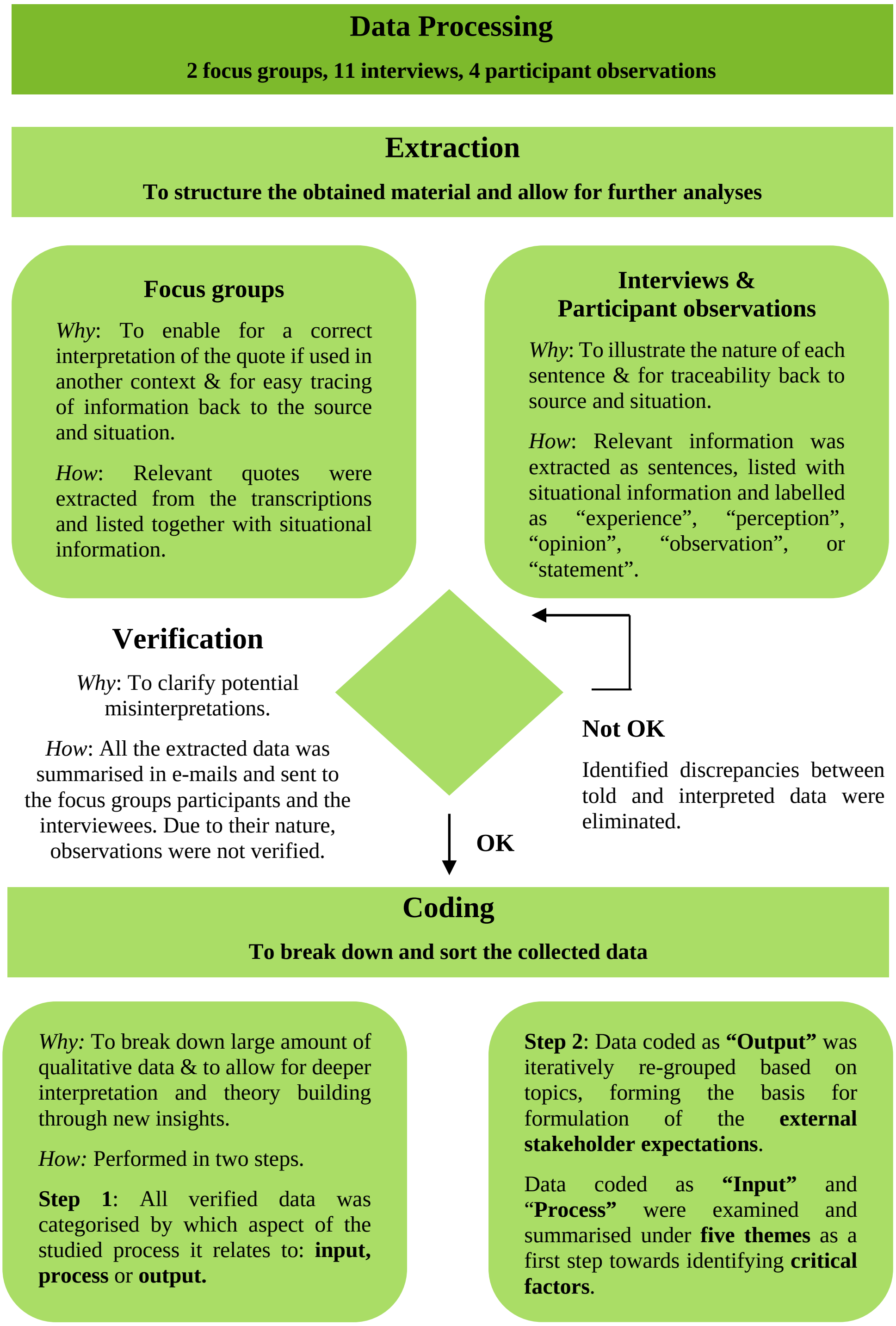

Figure 3.2 Illustration of the raw data processing showing the stages of extraction, verification and coding.

3.5.1 Extraction and Verification of Raw Data

When concluding the raw data collection phase, the amount of data obtained was extensive and covered a wide range of aspects. In order to structure the material and allow for deeper interpretations, information connected to the research questions was extracted and processed as described below.

The material from the focus groups was transcribed from the recordings of the sessions, a typical first step of data analysis in qualitative studies (Dalen, 2008). Documenting the whole discussion in text format makes it easily available for verification of the verbal information exchange during the focus group sessions but it should be stated that all non-verbal and contextual information is lost, together with the tone of voice. In the next stage, all relevant quotes were extracted from the transcriptions and listed together with additional information in terms of speaker, context and reactions from other participants so that each quote was self-dependent. This was done so that quotes could be re-arranged and, to as large extent as possible, correctly interpreted in another context later in the analysis. It also enabled easy tracing of information back to the source and situation.

Out of the 14 conducted interviews, all eleven discussing engine development were included in the data processing stage. Even though two of them were part of the pre-study, all contained valuable information and were therefore processed in an equal manner. While transcription of the data makes for highly reliable interpretation of data, it is also time consuming. For the interviews, relevant information was thus instead extracted as short sentences, interpreted from the meeting minutes, although recordings had been made. Each sentence was labelled with speaker and situation details for traceability. To illustrate the nature of each sentence, they were also labelled with either “opinion”, “perception”, “experience” or “statement” of the interviewee or “observation” by the interviewer. The reason no information was labelled as a fact is that the word implies that the information is general and true independently of the source of information, which cannot be assumed from isolated interviews and hence the label “statement” was used instead.

Information from participant observations was extracted from taken notes and compiled in the same manner as the information from the interviews. No recordings were made during observations for practical reasons. Thus, the information collection and the labelling rely on notes and the authors’ real-time interpretations.

It is important to ensure that the interpreted material corresponds to the perception of the sources of information (Höst et al., 2006). Therefore, before the analysis was performed, each interviewee was sent a summary of the extracted material from their interview and given the opportunity to clarify potential misinterpretations. The feedback was taken into consideration in order not to draw conclusions from distorted information. Identified discrepancies between told and interpreted data were eliminated. Additionally, the internal supervisors served as a third party in reviewing the information by casting new light on the material.

3.5.2 Coding of Data

Coding is a useful method to break down and analyse large amounts of qualitative data. It begins with going through the material carefully to create an understanding of which type of information has been collected, after which data can be sorted under suitable categories (Dalen, 2008). Organising the data in new ways is a stepping stone to deeper interpretation of the material and new insights. A suitable first categorisation for this study was found to be differentiating of the data based on which aspect of the studied process it discusses, as illustrated in Figure 1.1. These categories are:

- Input. What do the external stakeholder ask for and how do the requirements reach other key stakeholders?
- Process. How are the requirements interpreted by the other stakeholders and what affects the degree to which they are met?
- Output. Which are the external stakeholder expectations of process output?

The “Output” category contains the information most relevant for formulating external stakeholder expectations and was further processed as described in Section 3.7.1. The “Input” and “Process” categories still contained an amount of information difficult to manage despite the screening in the extraction stage, wherefore the data underwent an additional level of coding before critical factors could be identified. In this further processing of the information, editing methods was used to extract keywords from the collected material, sorting it based on the authors’ perception of the data (Höst et al., 2006). Similar information within the categories “Input” and “Process” was then grouped together so that various themes were derived, which are presented in Section 5.2.

3.6 Corroboration of Data

When using data from a small population in research, a disadvantage is the non-applicability of the result on other populations or in other situations than the studied one (Bryman, 1992). As the “truth of the matter” is most likely unique to each participant, a veracious version of the processes and the experienced flaws cannot be obtained and Patton (1999) points to the fact that different data collection methods can yield varying results due to sensitiveness of real world nuances. Also, themes and conclusions drawn from the collected material are formulated by the authors and are thus subject to misinterpretation. However, corroboration can be sought by applying triangulation (Pierce, 2008). In this study, triangulation was commonly realised by supporting findings with data from various sources or by comparison with documented material. For some areas, collected information was however not deemed sufficient for triangulation.

Another method for triangulation of the data was therefore to use surveys in the form of questionnaires, which is a preferred method when researchers want to answer "what" questions and is applicable when no control of behavioural events is needed (Yin, 2009). The basis for constructing the actual questionnaire is a clear definition of research questions, goals with the survey, target population and analysis method of obtained results, which together set the framework for which survey method to use and which respondents to target (Blair & Czaja, 2005). Key decisions also include the type of information to be collected and how it is best elicited from the chosen respondents, as well as eventual priorities between multiple goals (Blair & Czaja, 2005). A survey can be designed and distributed in many ways, all of which have their advantages and drawbacks, see Table 3.7. Care should be taken to select the method most suitable for the purpose and nature of the study as e.g. the likelihood of cooperation from respondents can vary depending on the method of data collection (Blair & Czaja, 2005). Also, the task should always be made as easy as possible for the respondents, in order to reduce reasons not to respond to the survey (Czaja, Blair & Blair, 2014). The sampling frame is the list of people within the target population accessible as respondents and a key to successful sampling is to locate knowledgeable informants, i.e. questionnaire respondents, within this sampling frame (Blair & Czaja, 2005).

Table 3.7 Comparison of major survey methods, table recreated from Blair and Czaja (2005).

Aspect of survey	*Mailed questionnaires*	*Internet surveys*	*Telephone interviews*	*Face-to-face interviews*
Administrative, Resource factors				
Cost	Low	Very low	Low/medium	High
Length of data collection period	Long (10 weeks)	Very short/short (1-3 weeks)	Short (2-4 weeks)	Medium/long (4-12 weeks)
Geographic distribution of sample	May be wide	May be wide	May be wide	Must be clustered
Questionnaire issues				
Length of questionnaire	Short/medium (4-12 pages)	Short (< 15 minutes)	Medium/long (15-35 minutes)	Long (30-60 minutes)
Complexity of questionnaire	Must be simple	May be complex	May be complex	May be complex
Complexity of questions	Simple/moderate	Simple/moderate	Must be short and simple	May be complex
Control of question order	Poor	Poor/fair	Very good	Very good
Use of open-ended questions	Poor	Fair/good	Fair	Good
Use of visual aids	Good	Very good	Usually not possible	Very good
Rapport	Fair	Poor/fair	Good	Very good
Data-quality issues				
Sampling frame bias	Usually low	Low/high	Low	Low
Response rate	Poor/good	Poor/good	Fair/good	Good/very good
Response bias	Medium/high (favours more educated people)	Medium/high (favours more educated people)	Low	Low
Knowledge about refusals and noncontacts	Fair	Fair	Poor	Fair
Control of response situation	Poor	Poor	Fair	Good
Quality of recorded response	Fair/good	Fair/good	Very good	Very good

3.6.1 Survey to Design Engineers

From the collected data, themes such as communication, and communication of requirements in particular, were derived. Multiple sources had mentioned information connected to these as potentially affecting the extent to which external stakeholder expectations are met during a project. Much information also converged towards activities performed by design engineers, out of whom only one had been interviewed. Hence, these were targeted as a population for corroboration of data, and a questionnaire was formulated to find answers to the second research question.

3.6.1.1 Goals of the Survey

Based on above, the aim of this survey was twofold:

1. To expose the findings to a large group with cross-functional insight to support the triangulation process, enhance the validity of further analysis, and to allow to draw more general conclusions about the current state.
2. To receive designer engineers' views of the process as it is performed today.

Both goals were important to include in the design of the survey, but the first was given higher priority. Enhancing the validity of the qualitative analysis was deemed of great importance for the further analysis process and formulation of the critical factors, whereas additional input was seen as valuable for the recommendations.

3.6.1.2 Choice of Survey Method and the Sampling Frame

Internet survey was selected as method as it was believed to increase the cooperation of respondents by offering them flexibility in when and where to respond. Other possibilities were discussed, such as distributing the survey face-to-face to design engineers, but this was considered to interfere with their daily work to greater extent, thus potentially lowering the data quality. Another advantage with the survey method was that the responses would be presented electronically, eliminating the work of manual input. As presented in Table 3.7, Internet surveys also provide a means of gathering information within a short data collection period, which was suitable in this case and they can according to Czaja et al. (2014) make fairly good use of open-ended questions. An important requirement for using this method is that the questionnaire must be self-explanatory (Blair & Czaja, 2005).

The sampling frame included design engineers working with engine components at the engine development department at Scania Södertälje, a total of approximately 90 people. This group could be unequivocally identified, which is important for the target population of choice (Blair & Czaja, 2005). The group also met the criteria of having considerable knowledge about the information to provide, since embedded in the work tasks, hence were considered as qualified informants.

A risk that had to be considered was the low control over the response rate that the Internet survey design yields (Blair & Czaja, 2005). To counteract a low response rate and a long response time the survey was discussed with managers within the engine development department. These provided the authors with lists of names on employees with less workload, meaning the specific subgroup of respondents was mediated, to finally include 32 names. This can be labelled as a non-probability sample, where the design engineers did not have an equal chance of being selected, but rather was recruited using social gatekeepers, whom in turn nominated a group of people who met the requirements for the research sample (Pierce, 2008).

The authors chose to mainly use closed-ended questions, since they are easier to interpret and was believed to well serve the first goal of the survey. The Likert scale was selected since it is the most widely used instrument when performing a survey which aims to examine attitudes, in this case about a number of activities and relationships. It is an ordinal scale where the respondents are presented to a point scale (commonly five, seven or nine) of pre-coded responses ranging e.g. from strongly disagree to strongly agree (McLeod, 2008). This way, individuals are allowed to express how much they agree or disagree with a particular statement, which was a desirable characteristic for the study. As the questions in the questionnaire were separate, i.e. the authors did not to seek to combine the responses from the items into a composite scale upon analysis, they fall into the category of Likert-type items and should be analysed as such (Boone Jr. & Boone, 2012).

The choice of Likert response alternatives fell upon using a four point scale, omitting the neutral option. This was decided in collaboration with the supervisors, to enhance the possibility to distinguish tendencies among the responses. In order to better support the second goal, the survey also included some yes/no statements and lastly also open-ended questions with the purpose of gaining deeper understanding of the process as experienced today. In order to facilitate for the respondents to give full answers to these, the survey was designed and distributed in Swedish. It can be found in translated form (freely translated from Swedish to English) in Appendix A.

3.6.1.3 Pre-Testing of the Survey

Since no interviewer was to be present while conducting the survey, the pretesting of the developed survey served the important purpose of ensuring that the questionnaire was self-explanatory and that the design appeared to the respondent in the intended way. As a first step, an informal trial was performed with the supervisors, in order to check the language and that the questions were interpreted as intended. Next a session with a design engineer was performed in order to thoroughly discuss all survey statements to ensure that a correct language was used, the statements were valid and corresponded to what the authors intended to ask. This aimed to minimise survey errors steaming from misinterpretations.

Examples of questions (two for each purpose described above):

- Does it reflect the parlance used in their role?
- Is the meaning of the statement affected by some particular words or the structure of the sentence?

- Are the statements deemed as relevant to their role?
- Is it possible for a design engineer to respond to the statements?
- How is the statement perceived in the eye of a design engineer?
- Are there any risks of misinterpretations?

The design engineer reviewing the survey draft was excluded from the sample, in order to minimise the risk of response bias. After the feedback session, changes were made in the survey accordingly and an option of "Do not know" was added, since a few statements were deemed complicated to answer to if the engineer had not worked in a particular way. The survey was then created as a digital version and sent out to another design engineer, who was instructed to give feedback regarding time consumption and statements subject for misinterpretation. This step only resulted in a minor change in one statement, not believed to affect the respondent's answer to this, therefore the design engineer was considered as part of the sample. After this, the survey was considered ready for final distribution.

3.6.1.4 Distribution of the Survey

The questionnaire was sent via e-mail to the sample, together with a cover letter written to trigger participation. It included the purpose of the survey, a description of the authors, why the respondent was chosen and why their response was regarded important and included an assurance of confidentiality. To avoid respondents skipping questions, they were all made as required fields in the web survey. Lastly, contact information was provided if respondents wished to ask questions or needed guidance to respond. After a week, an e-mail was sent out to all as a reminder to trigger more responses. Since the sample was rather small, it was important that the design engineers represented different departments and that the response rate were as high as possible.

3.6.2 **Survey to Line Assemblers**

Line assemblers are an important part of the engine assembly stakeholders and the conducted line practice yielded valuable findings on their views of the product and process. Out of two assembly lines, 13 areas in total, only one area was however targeted for observation, inducing a large risk of bias to the findings compared to other collected data. Further, line assemblers typically have deep knowledge of a smaller part of the process, rather than general knowledge of the assembly process as a whole, so told information could not be assumed as representative. In order to reduce this bias of the findings, a survey was developed with line assemblers at DE as the target population. The purpose was to test a number of working hypotheses constructed from previously collected data with the goal of generalising the findings and ensure reliability of the data before proceeding to the formulation of external stakeholder expectations.

A survey in paper format, distributed face-to-face was selected the optimal method, primarily based on the convenience for assemblers to perform the task of filling it out, a crucial factor according to Czaja et al. (2014). Alternative methods such as Internet surveys and telephone interviews would not allow for the surveys to be filled out by the assemblers during their work days. Further, mailing surveys for distribution by line managers would be in conflict with the decision to treat responses confidentially. While the selected method is a hybrid between mailed questionnaires and face-to-face interviews as presented in Table 3.7, the advantages or disadvantages of the two methods are not applicable for most aspects with the described format. For example, the schedule of assemblers was a much higher restriction in questionnaire length than the method itself. While the approach requires the participation of the authors, the time requirement was reduced by handing out the survey to small groups of respondents simultaneously.

A majority of the questions were formulated as statements for the respondents to evaluate on an interval scale, based on their degree of agreement. Each extreme end of the statement was supported by a statement corresponding to strong agreement and strong disagreement respectively. By using statements, respondents were steered towards the exact dimension targeted by the authors and the risk for misinterpretation of the questions was reduced. A six-point scale was selected for high resolution of the responses and to omit the neutral alternative.

The sampling frame consisted of assemblers on the two engine assembly lines at Scania Södertälje, 320 people in total. Out of these, a sample of 16 respondents was selected by social gatekeepers. While the aim was to get a diverse sample, the work load of the areas and personal engagement among line managers and assemblers affected the selection process and the final sample spanned three areas located relatively early on the line, whereof one was the area previously observed. The work schedule of the assemblers only allowed for ten-minute long surveys which set the outlines for the questionnaire design. The final version was thus only two pages long and consisted of twelve statements evaluated on an interval scale, followed by two multiple choice multiple select questions. As up to three alternatives could be selected by each respondent for the last two questions, it allowed for more differentiation between the options than a single select format.

To ensure clearly understandable terminology and phrasing of the survey, a draft was reviewed by a line manager. After one minor correction it was then distributed to the sample of respondents. The authors were present during the distribution to explain the purpose of the survey and collect the responses, so that middlemen could be avoided. Confidentiality and anonymization of the results was stated clearly upon distribution to avoid respondents feeling inhibited when answering. The survey was written in Swedish to avoid language barriers. A translated version, freely translated from Swedish to English, is presented in Appendix B.

3.7 Formulation of Results

In this section, the process of formulating the results from available material is described. It is divided into two parts: one about the formulation of external stakeholder expectations and one about the critical factors affecting their fulfilment.

3.7.1 External Stakeholder Expectations

The goal of the formulation of external stakeholder expectation was to, from all available information, extract the needs and wishes of selected stakeholders and support these with a clarification of the value they bring to the company. With available information is here meant all information from the raw data collection falling into the "Output" category, i.e. being related to the expectations of the external stakeholders on the process output. Note that information could come from any of the key stakeholders, as long as they discussed the expectations of the external. With clear labels on all pieces of collected data, information from the external stakeholders themselves could still be easily distinguished. The ground principles for formulation of external stakeholder expectations was that they must be detailed enough to serve as guidelines in the development process but still on a generic level, applicable for any type of project.

External stakeholder expectations were identified by iterative re-grouping of data, based on discussed topics. To clarify their value, they were each connected to one or more high-level objectives formulated by the authors. The reason for constructing a new set of high-level objectives instead of using the existing, cross-functionally governing core values of the company ("customer first", "respect for the individual" and "elimination of waste") was that it was found difficult to relate the expectations to these core values without a loss of clarity. Using the more detailed existing principles also proved unfeasible as these are unique to each function, which goes against the cross-functional approach of this study. With a new set of high-level objectives, sub-ordinate to the core values, expectations from several functions can be connected to the same value while the benefits of meeting each expectation is clearly emphasised. Moreover, the new high-level objectives were inspired by the collected data which confirms their relevance to the study.

Formulation of the high-level objectives was based on a few pre-defined ground principles set by the authors. Each objective must be unarguably beneficial for company profitability or survival and applicable for a variety of Scania functions, not only those studied. They must all be aligned with the long-term strategy of Scania which includes their implemented lean strategy summarised as "The Scania House" (see Section 2.2). Moreover, the objectives must not overlap and the set of objectives must be comprehensible enough for all collected data to clearly relate to at least one. Efforts were also made to keep the list short, as an easy overview of the objectives facilitates usage.

Identified external stakeholder expectations were found to often relate to more than one high-level objective. In the final list, they are thus complemented with information on how they are connected to each one applicable. With these connections clearly visible, an explanation is provided of how fulfilment of the expectations contributes in creating value for the company. Thus, the first research question is covered by the methodology.

3.7.2 **Critical Factors**

The goal of the formulation of these factors was to provide an understanding of what affects the project output, in this case how well the external stakeholder expectations can be met during new product development projects. Therefore, all the collected data falling into the "Input" and "Process" categories, i.e. is related to the information flow and the procedures in the development projects, formed the basis from which the factors were crystallised. A criterion used in the drawing of the list was that each factor had to be substantiated by data from more than one source due to reliability reasons.

The results from the survey sent out to design engineers at NM added insights relating to the themes, thus strengthened the basis from which the factors were formulated. Since the data used was gathered from all key stakeholders included in the study, and additionally substantiated by information collected from other functions within the company, the factors are based on perspectives and perceptions from a wide range of representatives of the NPD process. Examples of what inspired the factor formulation are expressed experiences of several phenomena, problematic interfaces and collaborative activities, all positively or negatively affecting the project outputs.

An awareness of the factors can be valuable to the company as they provide aspects to take into account when initiating and working in development projects, in order to meet stakeholder expectations and increase the predictability of product development project output. By this, the second research question is covered.

4 Literature Study

This chapter provides a description of lean product development, organisational learning and integration over functional interfaces, the three main topics of the literature study. Presented information was used in the interpretation of material gathered during the study of Scania, in the analysis of the results and to draw well-grounded conclusions.

4.1 Lean Product Development

Ulrich and Eppinger (2012) define product development as the set of activities starting by the identification of a market opportunity and leading up to production, sale and delivery of a product to the customers. This very broad definition is common in literature but to better correlate with Scania terminology, the CD stage which is generally included in the PD process is throughout this thesis regarded as a separate, precedent process. A simplified illustration of a common approach to CD and PD is shown in Figure 4.1, the yellow colour marking the stages of concept development and the green colour symbolising the product development stages, with here used definitions. Although the simplified process appears linear, it should be emphasised that the stages of product development is in practice typically cross-functional, carried out in parallel and in a more iterative manner than indicated by the linear model (Cooper, 2008).

Both CD and PD come with a number of challenges and a company's success in the area is commonly evaluated in five dimensions; product quality, product cost, development time, development cost and development capability (Ulrich & Eppinger, 2012). This section discusses the topic of lean product development, an approach to CD and PD aiming to improve its success in above mentioned dimensions using the core ideas from lean thinking.

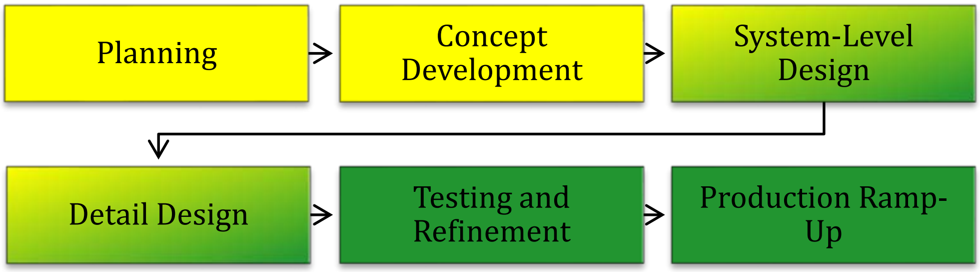

Figure 4.1 Common steps of the product development process, recreated from Ulrich and Eppinger (2012). The colouring illustrate the correspondence with Scania's CD (yellow) and PD (green) processes at explained in Section 2.3.

While the term lean was initially used in a manufacturing context, the philosophy stretches beyond that and is now accepted by both researchers and practitioners as an improvement strategy for the product development process as well (Khan et al., 2013). Compared to manufacturing processes, engineering design processes are characterised by a greater uncertainty, since the output cannot be known in detail on beforehand. The flow in product development also differs in the sense that it is more difficult to grasp as it consists of information and many engineering processes also include on jobs of varying size and complexity as opposed to more homogeneous manufacturing jobs (Morgan & Liker, 2006). Through appropriate adaption, lean theory can however be extended to PD and provide substantial leverage both in terms of creating of the right product and as an enabler for of lean production (McManus, 2005).

Moving towards a lean process does not necessarily include abandoning the activities of conventional product development, but is rather a question of optimising the process and making it lean by conducting the activities according to lean principles (Cooper, 2008). That can include re-arrangement of activities or re-allocation of resources between activities. With the concept of LPD being rather immature, there is still a lack of consensus regarding its definition among both practitioners and researchers, although many core concepts are agreed upon and Toyota is generally acknowledged as the forerunner (Khan et al., 2013). Through an extensive literature study, Khan et al. (2013) identified five distinctive categories of approaches to LPD based on concurrent engineering, lean manufacturing, the Toyota PD process or a combination of these. Analysing the categories, they conclude a Toyota-centric approach to LPD is the superior alternative, as the success of Toyota's PD system is the result of lean-inspired methods developed internally rather than based upon previous PD approaches used by other companies. Moreover, they argue that manufacturing systems differ from PD processes in a number of critical ways as previously explained, so theory should be adapted to fit the PD process characteristics instead of being derived directly from lean manufacturing principles. The Toyota principles and case studies of their PD system therefore lays ground for the definition of LPD described and used in this thesis.

The study by Khan et al. (2013) also resulted in the identification of five core enablers to LPD, namely set-based concurrent engineering (SBCE), chief engineer technical leadership, value focused planning and development, knowledge-based environment and a continuous improvement company culture.

4.1.1 Ground Principles for Lean Product Development

Khan et al. (2013) defines LPD as value focused PD, where value is determined by customer needs and desires and SBCE is the enabler to value creation in the process. This definition goes well in line with core concepts of lean thinking: customer focus, value creation and elimination of waste. One challenge with LPD, as opposed to lean manufacturing, is that it is not always obvious how to achieve lean flows as the process involves intangible outcomes and iterative activities to much higher extent, resulting in a seemingly fuzzy process for the untrained eye (McManus, 2005). Through extensive studies of Toyota's product development system, LPD has however been identified to follow 13 ground principles as presented in Figure 4.2 (Morgan & Liker, 2006).

The process subsystem

1. Establish customer-defined value to separate value added from waste
2. Front-load the product development process to explore thoroughly alternative solutions while there is maximum design space
3. Create a levelled product development process flow
4. Utilise rigorous standardization to reduce variation, and create flexibility and predictable outcomes

The skilled people subsystem

5. Develop a chief engineer system to integrate development from start to finish
6. Organise to balance functional expertise and cross-functional integration
7. Develop towering technical competence in all engineers
8. Fully integrate suppliers into the product development system
9. Build in learning and continuous improvement
10. Build a culture to support excellence and relentless improvement

The tools and technology subsystem

11. Adapt technology to fit your people and process
12. Align your organisation through simple, visual communication
13. Use powerful tools for standardisation and organisational learning.

Figure 4.2 The 13 principles of lean product development (Morgan & Liker, 2006).

4.1.2 **A Zero Waste PD Process**

Principles 1-4 in Figure 4.2 are guidelines to achieving an efficient PD process, from initiation and concept development up until development is finished and the product goes into production (Morgan & Liker, 2006). The main challenge here can simply be put as waste reduction, which is a multi-faceted expression. In order to reduce waste, customer value must be clearly defined and creation of that value must be the goal of every activity in the process, as to avoid situations where efforts are spent on fulfilling a need that never existed. Although seemingly straight-forward, this is a huge challenge as internal preferences, i.e. engineers taking pride in great technological performance of the product, and customer preferences are not always aligned. Also, the mind-set of customers is complex and ever-changing so understanding and dynamically adapting the goals of the PD process to the market environment at time of product launch can be tricky and have a significant impact on the competitive advantage of a company.

Another source of waste is rework caused by late design changes in the PD process, which easily occur in situations where a large range of possible solutions exist, such as during NPD. A useful practise to eliminate this waste and ensure rapid convergence towards optimum is SBCE (Sobek II, Ward and Liker, 1999). Sprung from Toyota practises and tightly linked to both concurrent engineering and lean theory is has been identified as a core enabler for LPD, by some even as *the* core enabler (Khan et al., 2013). SBCE differs from regular concurrent engineering in that whole sets of solutions are evaluated simultaneously during the design process and is described by Sobek II et al. (1999) to work as follows: In the beginning, the set is large and can involve a great variety of solution approaches to a given task. The set is repeatedly evaluated by a cross-functional team throughout concept and product development process, giving several functions the opportunity to follow the design process and select their preferred subset of solutions from the range. Each round of evaluation thus provides design engineers with information on which solutions have the greatest potential from a cross-functional perspective so that these can be designed in more detail. At the first evaluation session, the solutions are still on a very conceptual level but as the set is reduced in size, the solutions are further developed until the process has converged to one fully specified, optimal solution. Ideally, reaching this optimum does not require any rework loops. An additional advantage is that involved functions such as the assembly function can begin their preparations as soon as all proposals within the set are sufficiently similar to each other (Sobek II et al., 1999).

With much effort placed on the early design stages and by avoiding settling for one solution before multiple have been assessed, SBCE is highly aligned with the second of the LPD ground principles in Figure 4.2, to front-load the process to explore the whole design space (Morgan & Liker, 2006).

4.1.3 The Role of People in Lean Product Development

The subsystem “skilled people” refers not only to recruiting skilled engineers and managers but also to give them proper training and a continuous competence development throughout the employment through e.g. mentor programs (Morgan & Liker, 2006). A great emphasis is also put on a functional chief engineer system where projects are managed through technical know-how and with the same manager being responsible for the entire project (Khan et al., 2013). In an automotive manufacturing company the chief engineer is assigned responsibility for the total vehicle, from early concept development to launch, and the system ensures someone is always accountable so that matters cannot fall between the chairs (Morgan & Liker, 2006).

Learning and continuous improvement depends heavily on the employees and has been described as “the most powerful competitive weapon” of a lean enterprise, demonstrating the importance of people (Morgan & Liker, 2006). This topic will be treated separately in Section 4.2.

4.1.4 Tools and Technology Supporting Lean Product Development

Tools and technology are, in a lean company, means to support the process and the people and are not core enablers in themselves (Khan et al., 2013). Nevertheless, used correctly they can provide sufficient leverage. The problematic with for example software tools or rapid prototyping technology is that they are rarely unique to the company, hence should not be relied solely upon for competitive advantage however powerful they are. Seamless integration between technologies and with the process is far more important than isolated excellence of one single technology and care should be taken to ensure they complement the expertise of employees rather than aiming to replace it. (Morgan & Liker, 2006)

In building technical competence, a lean company relies heavily on human capital and passed-on knowledge from more senior engineers to more junior (Khan et al., 2013). Simple check-lists, design guidelines and knowledge databases are all promoted as superior to more complex guides, considered to take up more time than they bring value for experienced engineers (Khan et al., 2013). Even as a lot of emphasis is put on simple tools when it comes to lean engineering, it should be stressed that many advanced tools are also great enablers. Computer-aided design and computer-aided engineering software, for example, are both great facilitators to concurrent engineering as they enable designing directly in an integrated product environment which can be extended to include surrounding parts or work stations (Morgan & Liker, 2006).

4.2 Organisational Learning in Lean Enterprises

A key objective of LPD is the continuous improvement of processes (Schulze et al., 2013). As earlier mentioned, learning is essential as a competitive weapon for a lean enterprise (Morgan & Liker, 2006). The supposition is that innovative ideas occur to individuals, not to organisations. Hence, by seizing individuals' and groups' knowledge and learning about the processes, turning it into standards which are passed down to others and deployed in the organisation, it can manage the critical activity of capturing tacit knowledge (Morgan & Liker, 2006). The use of tools for OL is one of the ground principles of LPD but even though the topic has been around since 1965, no shared understanding exists (Schulze et al., 2013; Crossan et al., 1999). This is explained by that the concept has been applied to different domains with diverse underlying phenomena of interest, taking disparate perspectives, as summarised in Table 4.1.

Table 4.1 Propositions applied to established Organisational Learning frameworks. Recreated table from Crossan et al. (1999).

Source	*Strategic renewal tension*	*Multilevel framework*	*One level affects the others*	*Cognition/action link*
March & Olsen (1975)	Not considered	No group level	Not considered	Yes
Daft & Weick (1984)	Not considered	Not considered	Not considered	Learning is a change in behaviour
Senge (1990)	Not considered	No organisational level	Not considered	Yes
Huber (1991)	Not considered	Yes	Not considered	Cognition affects behaviours
March (1991)	Yes	No group level	Not considered	Yes
Watkins & Marsick (1993)	Not considered	Yes	Not considered	Consistent with Senge's perspective
Nonaka & Takeuchi (1995)	Not considered	Recognized, but not a substantial part of the model	Some discussion of the link between individual and group	Knowledge focus

It is important to ensure that individuals or functions develop a common version of knowledge base as own versions can lead to inconsistencies (Morgan & Liker, 2006). Morgan and Liker (2006) also describes standards as a means to lay ground for the inclusion of engineers being active participants in the learning process.

A framework that embraces several major OL schools of thought is the comprehensive and widely recognised 4I framework developed by Crossan et al. (1999). It addresses a tension between what is referred to as exploration and exploitation, and that this is found at the heart of strategic renewal; requiring the organisation to explore and learn while concurrently exploiting what has already been learned (Schulze et al., 2013). The transference of learning from individuals and groups to learning embedded in the organisation, in the form of systems, strategies, procedures and structures, are related to exploration, according to Crossan et al. (1999), whom label this a feed forward process of learning. When the institutionalised learning instead affects the individuals and groups, this is labelled a feedback process connected to exploitation (Crossan et al., 1999). These processes can be seen in Figure 4.3 below. The 4I framework of organisational learning also takes into consideration that these processes occur across three learning levels, namely: individual, group, and organisation, and that they are linked by the social and psychological processes of: intuiting, interpreting, integrating and institutionalising (Crossan et al., 1999).

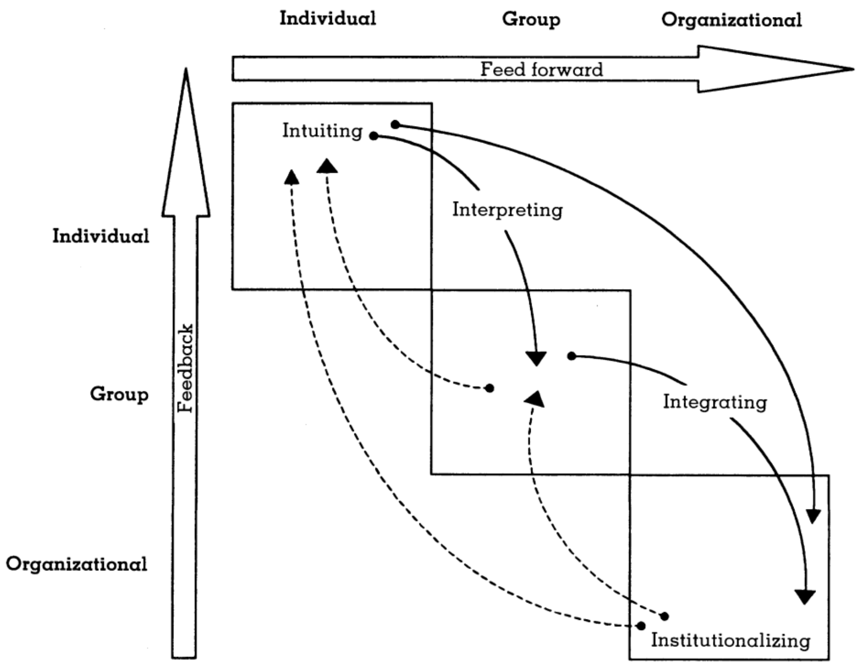

Figure 4.3 The 4I framework illustrating the feed forward and feedback processes across the three learning levels: individual, group and organisational. Picture retrieved from Crossan et al. (1999).

4.2.1 The Four Processes

Intuiting

Defined as a subconscious process of (past) pattern recognition. By repeatedly being in the same situations, actions will no longer require conscious and deliberate thought. This process can guide the actions of an individual but cannot affect others since there is no language to describe the insights. Expertise is therefore hard to transfer since it is highly subjective, making it difficult to surface and explain. (Crossan et al., 1999)

Interpreting

The process of explaining an idea through words or actions, sharing it at group level. Interpreting takes place in relation to a domain within which individuals and organisations operate, and from which they extract data. This is a social activity; by surfacing the ideas, a language is developed which underpins the creation of a shared understanding through conversations. (Crossan et al., 1999)

Integrating

A shared understanding is developed among individuals through mutual adjustment, i.e. behavioural change. Initially this will occur informally but if dialogue and joint actions are undertaken a coherence can evolve. By continuous conversation the language develops and allows for the evolution of a deeper shared meaning at a group level. (Crossan et al., 1999)

Institutionalising

This process sets OL apart from individual or ad hoc learning, indicating that some learning becomes embedded in the organisation. The occurrence of routinized actions is ensured by defining tasks and establishing mechanisms. This is a means for organisations to leverage the learning of the individuals, which come to guide the actions and learning of its members. The repetition of routines is facilitated but on the other hand experiences and events are interpreted through the context, which may impede interactions and the organisation’s ability to respond to its surroundings. (Crossan et al., 1999)

4.2.2 Challenges and Facilitators of Organisational Learning

Crossan et al. (1999) mean that changes in the institutionalised organisation (e.g. in structures and routines) occur rather infrequently and that these are typically punctuated, whereas the three other processes are more continual. Moving from intuiting to institutionalising and the other way around is therefore an iterative process, meaning the nature of OL is dynamic. By conceiving learning as a dynamic flow, it can be recognised that bottlenecks may constraint the learning flow, just as can occur in production flow. Crossan et al. (1999) state two relationships as especially problematic; one dealing with feed forward process (interpreting-integrating), the other with feedback process (institutionalising-intuiting). The former provides a challenge in changing an already existing shared reality, where the starting point is to transform tacit knowledge to explicit ideas to call for a coherent action. The second tension deals with allowing subjectively based experimentation to take place in the institutional order within the established organisation. Institutionalisation can easily drive out intuition making individuals' learning become stockpiled, hence restraining the organisation's capacity to evolve and innovate. (Crossan et al., 1999)

Schulze et al. (2013) present a list of case studies in which researchers in the field have identified a number of OL facilitators. Among these, post-project audits, review sessions, best practice case studies and the presence of a learning culture can be found. In order to enhance the understanding of these facilitators, Schulze et al. (2013) used the 4I framework as a reference for OL when investigating the facilitating effects of value stream mapping in NPD processes. The results from their comparative case study show that it supports OL through facilitating the feed forward learning. An additional result is that representatives from different involved functions must be present in order for this to work efficiently. This is in line with Morgan and Liker (2006) arguing that individuals or functions should share the version of knowledge database and that the tools to be used across the organisation must be considered as valuable by the employees, otherwise information will be available but seldom used in creating value.

4.3 Integration over Functional Interfaces

Integration between the functions of design and manufacturing (where assembly is included) is a well-explored area in research while considerable less studies are available on the interface between the design function and that of service or R&M. This section therefore presents some general information on interface integration – its benefits, challenges and enablers – with an emphasis on the interface between design and manufacturing, followed by a description of practical methods available to integrate assembly and service requirements into the design.

4.3.1 **Benefits of Interface Integration**

When an organisation works as a unified whole the functional sub-units do not pursue their own agendas at the expense of overall organisational goals, and information is efficiently transferred, processed, interpreted and exploited. This can be described as achieved integration, and when high, the transfer is not only effective and timely but information channels are also deployed in an appropriate manner. On an organisational level, achieved integration focuses on information processing across the primary organisational functions: operations, product design/development, marketing/sales, for example the transfer of engineering blueprints from product development to manufacturing. From the information processing viewpoint, efficient flow of accurate information between these operations is crucial to raise awareness of the current manufacturing capabilities and what implications a change in the product design entails. (Turkulainen & Ketokivi, 2012)

Koufteros, Vonderembse and Doll (2001) present the view of an integrated approach, where an early involvement of many constituencies, such as manufacturing, is advocated. This provides the possibility to gather input from various groups, which can reduce the lead time from design conception to delivery of the product and allow for improvements in the level of innovation. Manufacturing is mentioned as a valuable source of insight; by suggesting ways to design the product with fewer parts or how it can easier be assembled or tested, reducing the risk of extending the product development projects due to engineering change orders, which is the most cited reasons for delays (Koufteros, Vonderembse, & Doll, 2001). But, a dominance of one stakeholder perspective during the development process counteracts an achieved integration and can instead lead to conflicting views or lack of information, resulting in deficiencies in the ability of manufacturing to meet product design specifications (Turkulainen & Ketokivi, 2012). To counteract a bad alignment between the design and manufacturing, the learnings from previous projects can be captured and the organisation can develop design rules based on the knowledge of the manufacturing capabilities, which can be used as tools for the design engineers (Adler, 1995). Integration is thus a cornerstone in reducing uncertainty, improving the communication between departments. When working cross-functionally, each team needs significant amounts of information input and must also provide the required information outputs, thus the interaction of functional representatives enables a rich information medium for reducing equivocality (Koufteros, Vonderembse, & Doll, 2002). Important to notice however, is that the mere use of cross-functional teams does not lead to a state where the organisation is integrated; doing something and being successful in something are not the same thing (Turkulainen & Ketokivi, 2012).

4.3.2 Challenges with Interface Integration

Vandevelde and van Dierdonck (2003) have summarised existing research on barriers which can exist in the interface integration between design and manufacturing, focusing on personal differences, cultural differences, language barriers, organisation barriers and physical barriers.

Personality differences between functions have been found in characteristics such as “Goals and Aspirations”, “Needs” and “Motivation”, where autonomy, a creative environment and knowledge creation are examples of hallmarks for design, whereas for manufacturing they seem to be clear tasks, organisational recognition and quality and volume at the requested time. (Vandevelde & van Dierdonck, 2003)

Regarding cultural differences, the functions differ in areas such as their view of time horizons, bureaucratic orientation and departmental structure. Trends that have been identified reveal that the same corporate goals are seen differently since differences between the functions affect the lens through which they are interpreted. The manufacturing function tries to realise economies and is output-oriented. The process focus tends to sacrifice long-term concerns in order to keep the operations going. In contrast, the design function prefers a longer time span and focuses on scientific development in a less bureaucratic environment. (Vandevelde & van Dierdonck, 2003)

The language barrier includes phenomena such as technical language and functional slang, which both facilitates intra-functional communication but constitute obstacles for the information transfer between functions. By this, the exchanged information can easily become misunderstood or interpreted incorrectly, which reduces the value of the piece of shared information. It is also hard to share information about intangible and abstract objects, which can be the case dealing with product development. Additionally, the level of detail used in the language may not match the level required for the job to be performed. Organisational barriers are seen in functional orientation where the own department's goals are perceived as more important than the ones of other functions. A lack of focus on the inter-dependency of tasks also constitutes a barrier, e.g. when production start-up gets postponed due to an attempt of shortening the development time by reducing the number of tests in place to ensure the manufacturability of the design. Lastly, physical barriers can be present if the development and manufacturing are geographically dispersed, which hampers informal and face-to-face communication. (Vandevelde & van Dierdonck, 2003)

Failure in overcoming the various barriers makes design-manufacturing integration difficult and may result in insensitivity towards the other departments, difficulties in understanding each other and a lack of agreement on important topics. It also negatively affects the use of transferred information. The perceived information utility is an important aspect of information utilisation and studies show that poor-quality, inter-functional relationships caused by integration barriers hinder the utilisation by reducing the credibility and comprehensibility to the receiver. (Vandevelde & van Dierdonck, 2003)

4.3.3 **Interface Integration Enablers**

Vandevelde and van Dierdonck (2003) state that the nature of the project may differ between task types and development stages, which affect the need of integration, but present two factors that generally facilitate the integration. First one is formalisation, such as structured processes and formal documents, which can be used to circumvent the various barriers. The former example provides milestones which can reduce procrastination whereas the latter require the sender of information to order and structure the thoughts on paper (Vandevelde & van Dierdonck, 2003). Incorporating criteria set by other functions in the design, for example by applying DFA principles, is also a way of structuring the product development process to facilitate cross-functional integration (Leaney & Wittenberg, 1992). To overcome organisational barriers, cross-functional teams are believed to be the most helpful. Vandevelde and van Dierdonck (2003) also presents a second factor, which is empathy towards manufacturing. This include that manufacturability should be explicitly thought about during the design stage, the attitude open-minded rather than negatively prejudiced and that an aspiration to take the manufacturing perspective into account exists. Design knowledge must also be cross-fertilised with manufacturing knowledge in order to combine how to technically develop new products and how to adequately produce them. If these facilitating factors are introduced, Vandevelde and van Dierdonck (2003) argue that the project nature (e.g. the degree of complexity of the developed product) no longer affects the smoothness of the production start-up.

On the other hand, other researchers identify the complexity of the developed product as a contextual factor that needs special managerial attention (Lakemond, Johansson, Magnusson, & Säfsten, 2007). They also identify challenges in the interface between product development and production and argue that integration problems are mainly caused by de-coupling of processes, namely when the industrial innovation processes are divided into three separate, but partly parallel sub-processes, i.e., technology development, product development and production. The authors provide insight into what factors are important in bridging these processes. In their study, six factors emerged as most important in the interface between product development and production, presented in Table 4.2 below. Transfer timing, what is being transferred and how it is transferred is defined as transfer synchronisation, transfer scope and transfer management (Lakemond, Johansson, Magnusson, & Säfsten, 2014). Hence, these are related to five out of six of the presented factors, the exception being the creation of a common vision.

However, all these conditions cannot be expected to be met in all projects, which are affected differently by the critical factors depending on the characteristics of the development project and the product (Lakemond et al., 2007). Through their research, Lakemond et al. (2007) also found six contextual factors which all affect the PD project and which have considerably support in the field. These factors are also presented in Table 4.2, said to hold project specific information which in turn affect the management of the project.

Table 4.2 The six critical factors in bridging the interface between product development and production, and the six contextual factors affecting the project and management style, found by Lakemond et al. (2007).

Critical Factors	***Contextual Factors***
Product manufacturability analysis	The complexity and degree of change in the product
Early production involvement	The complexity and degree of the change in the production process
Specific resources (note: e.g. time dedicated for production to participate in the PD process)	The degree of technological novelty
Continuous communication	The geographical and organisational dispersion between product development and production
Active involvement	The geographical and organisational dispersion between technology development and production
Common vision	The market uncertainty in the project

4.3.4 **Methods for Interface Integration**

Interface integration can be facilitated using hands-on methodologies or tools providing design engineers with guidelines on how the design can be adapted to the processes of other company functions, in this case assembly or service (which includes both repair and maintenance). Here two such methodologies are presented, the first one well-established and the second one considerably less mature.

4.3.4.1 Design for Assembly

Assemblability, or ease of assembly, describes the extent to which a product is adapted to manual or automated assembly operations. Design for assembly is the umbrella term for methodologies aiming to incorporate assemblability requirements into the design process and was coined around 1980 to describe recent work in the area (Leaney & Wittenberg, 1992). Many alternative DFA methodologies exist among which the most widespread are the Lucas DFA Methodology, the Hitachi Assemblability Evaluation Method and the Boothroyd Dewhurst System (Shetty & Ali, 2015; Leaney & Wittenberg, 1992).

The Hitachi Assemblability Evaluation Method is focused on the efficiency of part insertion, and part count is only penalised as it drives the product cost. With the Lucas DFA Methodology, designs are evaluated through a series of analyses of the product, part function, manufacturing (manual handling or automated feeding and gripping) and fitting, optimised for a given assembly sequence. The Boothroyd-Dewhurst System considers both part count efficiency, insertion and handling in the analysis. The design is then compared against an ideal product, with a minimal number of parts assembled in a minimal amount of time resulting in the design efficiency measure. (De Lit & Delchambre, 2003)

All above methodologies address quantitative assemblability evaluation of the individual products. For example, the design guidelines for the Boothroyd-Dewhurst Methodology include the themes of symmetries, part jamming or tangling, insertion resistance, reference axles, part positioning or location, fastener selection, obstructed part access and two-hand manipulation requirements while only one guideline extends the perspective to the whole product range. This guideline advocates standardisation by the use of common parts, processes and methods to benefit from economies of scale (Boothroyd, Dewhurst, & Knight, 2002). Research is being conducted on the integration of design with the whole assembly process but this is a much less mature field (De Lit & Delchambre, 2003).

4.3.4.2 Design for Service

Design for service, which covers both repair and maintenance with the definition of this thesis, is not as established as a term as the assembly analogy and also not as common to consider in the design process (Shetty & Ali, 2015). Still, there is plenty of ongoing research on both design for service and the bordering areas design for disassembly, design for maintenance and design for life cycle. A common incitement behind these efforts is sustainability of the design but disassembly cost is also mentioned occasionally (Germani, Mandolini, Marconi & Rossi, 2014).

Disassembly for repair and maintenance falls into the category of non-destructive, selective disassembly, which involves removal of only desired constituent parts of a product without damaging those surrounding (Desai & Mital, 2005). Occasionally destructive disassembly is used too, as long as the destruction is local, e.g. limited to a removed part. Mok, Kim and Moon (1997) have defined seven main criteria for easy disassembly as presented in Table 4.3. Although the criteria consider disassembly in a broader sense, they were originally presented in the context of disassembly for recycling. Another established methodology related to disassembly is AR^3T^3. It covers similar type criteria as listed in Table 4.3 but with a stronger focus on disassembly time and part access (Shetty & Ali, 2015). It also considers the re-usability and recyclability of removed parts.

Table 4.3 Criteria for easy disassembly as defined by Mok et al. (1997) and further explained by Desai and Mital (2004).

Criteria	*Explanation*
Disassembly without force	Excessive manual labour should be avoided
Disassembly by simple mechanism	
Disassembly without tools	Manual disassembly is to prefer
No repetition of using the same or similar parts	Part recognition is facilitated
Easy recognition of disassembly points	With disassembly points is meant joints which are to be disjointed
Simple product structure	
No use of toxic material in products	Manual labour is common, hence toxic materials are a health hazard

4.3.4.3 Implementing DFA and DFS in Industry

Tools for DFA and DFS can look very different, ranging from check-lists in paper format to sophisticated software tools, but the common denominator is that they inform the designer of the consequence of design choices on the product assembly process (Shetty & Ali, 2015). Important considerations when selecting a tool to implement is that it must provide complete assessment of the design and yield quick and accurate results without relying on the subjective judgement of the user (Boothroyd et al., 2002). Software-based methods are typically quantitative with little active involvement of the user, which is convenient but requires complete reliability of the tool. CAD software modules for disassemblability evaluation have also been criticised for not capturing all crucial factors of the real disassembly process, such as required manual force for part removal, ergonomics and accessibility issues (Desai & Mital, 2005). Looking at recently developed tools, progress seems however to be made on extending the list of evaluation criteria so as to include even the more intangible factors (Soh, Ong, & Nee, 2016).

5 Findings from Data Collection

In this chapter, findings from the data collection is presented in two rounds. The first section covers the general findings regarding the studied process, its input and output. It is followed by a more thorough description of the findings regarding the input and the process, sorted under four themes. The chapter lays ground for the synthesis of final results of the study. For confidentiality reasons, all material laying grounds for the findings cannot be published.

5.1 General Findings

Here is presented general findings regarding the studied process, its input and output as defined in Section 3.5.2 and visualized in Figure 5.1. The material is based on two pre-study interviews and the entire raw data collection: interviews, focus groups, participant observation and document studies. Results from the survey distributed to line assemblers are also included in the "Output" findings.

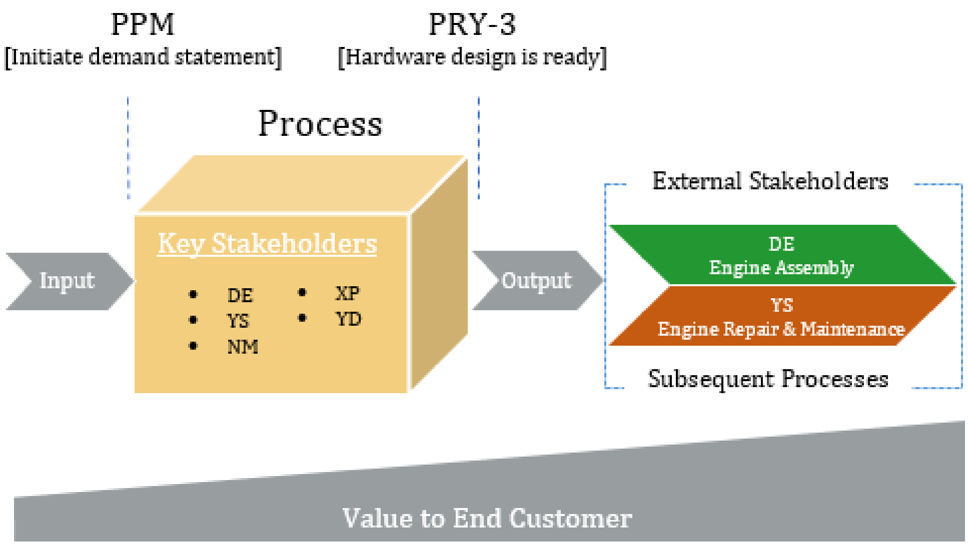

Figure 5.1 The scope of the study presenting the process boundaries and the classification of the studied key stakeholders.

Most information is related to the key stakeholders engine assembly (DE), vehicle service information (YS), engine development (NM), the project office (XP) and technical product planning & vehicle validation (YD), all shown in Figure 5.1. For these functions, the Scania abbreviations will be used for simplicity. While all five are value enablers in the studied process, the functions of DE and YS are also external stakeholders.

5.1.1 **Input to the Process**

The influential weight of the input to the project from involved functions varies depending on where in the process it enters. During the concept development, requirements are sometimes referred to as wishes, which can be explained by them not yet having been balanced against requirements from other functions (H. Henriksson, product introduction method and process developer, personal communication, April 25, 2016). Later in the process, from where the PDf and ODFs are approved during product development, requirements are already balanced and cross-functionally decided upon, thus treated as demands to be met rather than wishes.

While both YS and DE would like to start their involvement early in the CD process, it appears to be problematic to achieve in reality. An interviewee from DE indicated that even when DE is formally included in the CD teams, they sometimes feel excluded and experience a lack of transparency in the development activities. The earlier the concept can be reviewed in detail, the earlier one can act and draw up demands, according to a product engineer at DE. A common opinion among interviewed employees seems to be that the R&D function is the main contributor during concept development and some expressed they should get space to develop solutions without being crowded by other functions. This is confirmed by another source, working at YD, who comes with a different perspective on the same issue, namely that the CD process is intended to be carried out by small, fast-moving teams and be about cross-functional thinking rather than cross-functional participation. This can be achieved by recruiting highly experienced engineers as team members who can provide several perspectives to the project.

The difficulties in involving functions early on also includes differences in time perspective and one interviewee at YD wonders whether the engine assembly function even has the type of long-term goals required to work in the very early phases of the CD process, as the planned date for launch can be several years ahead. Also, interviewees from DE express that they need detailed specifications in order to participate, which are often not yet formulated in the CD process. Similar situations arise for the YS function, which state that they need specific information on e.g. part life length from the R&D function in order to quantify annual repair costs, an input they are expected to provide early on in the process.

5.1.1.1 Engine Assembly

For the engine assembly function, requirements are based on a self-developed DFA checklist, the Scania ergonomic standard (SES), a current state analysis of the system and production targets. This was stated by interviewees on managerial positions within the function. Out of these, the DFA checklist is the main tool for assemblability assurance and was found to be well established within the function, based on interviews with employees at DE and the engine assembly focus group. With the exception of one interviewed project manager saying such a list might exist, the DFA checklist was never brought up by anyone from NM or the project offices suggesting the list (or method) itself stays within the walls of DE although its implications are spread further.

The engine assembly function works in close contact with design engineers during the PD process, which is mentioned by interviewees from both DE, XP and NM, and they often meet at e.g. virtual build meetings or physical test assemblies. They also cooperate to some extent during CD, although a DE project manager expresses that the involvement is subject to improvement, as their own working process in these early stages today is unstructured. Another improvement opportunity was mentioned as the level of detailed of formulated requirements. Studies of PDfs from two projects showed input today is a mixture of very high-level requirements such as “no injuries” and more detailed ones. One of the studied projects is, by participants, considered as having been particularly well and thoroughly conducted. For that project, the PDf refers to the ODFs for detailed targets, in which the requirements are listed on a, for the authors, seemingly comprehensible level for each part. For the other studied project no similar ODFs were found, although less detailed versions existed for some objects. The high-level targets appear to be more of guidelines for DE during the project than an indication to design engineers of what is needed, while the more detailed are easier to relate to but not linked to what kind of value they bring.

5.1.1.2 Vehicle Service Information

Reparability and maintainability of the engine will affect the vehicle life cycle cost for the customers, hence the work of the vehicle service information function have great impact on the customer offer. Their early work, in the CD process, consists of reviewing proposals for concepts from an R&M perspective, giving recommendations on their feasibility and calculating predicted R&M costs, affecting the LCP of the vehicle for customers. A basis for the evaluation is that R&M costs should not increase compared to existing products and having the ability to calculate the relative costs of a proposed solution is expressed as vital.

The function has undergone a transformation in recent years regarding their level of participation in the projects, which has been noticed and confirmed by interviewees from several departments and functions. An interviewee with long experience at the function states that their increased involvement has contributed to them having a stronger influence on the project. Still, they are by several interviewees regarded as keeping a lower profile during the projects than DE. One provided explanation for this is that the function is rather small and do not have resources for attending meetings and actively communicating detailed requirements in all running projects. An engineer at YS emphasised the importance of active participation for all those involved by arguing that it enhances the understanding of the process output. If employees are aware of the difficulties other functions are facing and the requirement balancing situation, they are more likely to accept the result even when not optimal for their own interests.

In the engine R&M focus group as well as during an interview with a digital methods engineer, it became clear that much of the information transfer between YS and NM during the projects is made through direct contact between employees in the respective departments making it difficult for the authors to study. The AD and PDf from two running projects however confirm early involvement as R&M aspects are clearly stated and targets are sometimes project specific. Regarding the level of detail of requirements, the PDfs showed both high-level targets and more detailed ones in selected areas, similar to the targets from DE. A set of general targets and requirements of the vehicle service information function is developed to ensure inclusion of the most important aspects in every project (Johansson, 2014).

5.1.2 The Process

In a project, requirements enter from many functions and these must be understood and, if contradictions occur, balanced against each other before being incorporated into the design. The basis for making trade-off decisions appears to be an unstructured combination of input from involved functions together with deviation reports where the level of severity is specified. An interviewee at NM stated the decision-making in a project depends on the priorities of involved individuals, although legal requirements are the inarguable governing factors. For the functions of DE and YS it is not always clear upon which grounds decisions are made and a formalised method for decision-making is not mentioned by anyone. However, the ability to quantify the monetary effects of requirements is experienced to greatly affect the extent to which they are fulfilled.

It seems that the majority of the collaboration during projects revolves around the R&D function, in this case NM. Direct contact with other functions without inclusion of R&D seems less common and interviewees from both DE and YS indicate it is primarily used when they want backing in their argumentation, not for premature trade-offs.

Time was often mentioned to affect the process. A project manager exemplifies the reason to go through early generations quickly to meet time restrictions set by an early planned launch date. It was also found to affect the quality of the information transfer between CD and PD, when a project makes the transition between these processes. Available time at functions, tightly linked with available resources, was said to affect the extent to which employees from YS can participate in cross-functional meetings and during the engine assembly focus group it was lifted that since DE is mainly active late in the projects, poor time management in the early stages can affect the quality of their work and have consequences on the product introduction.

Another issue lifted in the study was the volume of the projects, i.e. the predicted number of products of that type to be produced, as affecting the quality of the project output. This was stated during both focus groups. For low-volume products it appears that one can afford less efficient solutions, based on statements from both DE and YS. An interviewee from YD further said that the same attitude could be seen at the R&D function. Small projects running in parallel with larger ones have quite low status according to a project engineer at DE, making investments and efforts hard to motivate.

5.1.3 Output of the Process

Apart from using the raw data collection as basis, findings on the output of the process are also based on results from the line assembler survey, as verification of the assembler perspective. Survey results were obtained from 16 assemblers and the mean and variance of their responses is here used to indicate the level of agreement of the population as a whole. Full survey results are presented in Appendix B.

A responsibility for DE is to produce (assemble) the developed product so that it can be provided to customers. With ever-increasing demands of production efficiency, a good alignment between product and production system is vital (S. Holmer, head of global product engineering, personal communication, March 8, 2016). During the engine assembly focus group, two ways of achieving alignment were brought up. The optimal way from their own perspective is to adapt the product to fit the production system. When this is not an option, the production system must change to fit the product. According to internal documentation, the product can be adapted to the production up until the milestone PRY-3 although interviewee experiences tell both that designs are often frozen much earlier than that, at least to some extent, and that design changes can be made after this milestone although geometrical changes are then rare. This is confirmed through studies of FRAS reports from two running projects. Although many activities revolve around part design, the uniform answer from participants of the engine assembly focus group about the most important enabler for alignment was not any physical characteristics of the product, but simply time. It appears most designs can be realised in the production system, as long as enough time is provided to review the product and to develop the production system accordingly before start of production.

The topic was also brought up with line assemblers, who are not involved in the preparations for product introductions on the line to the same extent (the exception being preparatory training sessions), but are greatly affected by the product/production system alignment once the product is introduced on the actual assembly line. Questions covered facilitating measures for avoiding assembly errors and general level of preparation upon product introduction on the line. The survey statements “Automated variant proofing equipment (e.g. scanners and cameras) work to efficiently avoid deviations” and “Visual aids for variant proofing (e.g. colour coding and pick-to-light) facilitate the assembly” were both agreed upon by the respondents, the sample means being 4.6 and 4.7 out of 6 respectively, where 6 represented full agreement. The same goes for the statements regarding product introduction “I feel well prepared to handle new engine variants when they are introduced” and “Upon introduction of new engine variants, tools and equipment are installed” which received mean values of 4.4 and 4.3 out of 6 respectively. Here should however be noted that the latter questions had a rather high variance, as seen in Appendix B.2, as a couple of respondents leaned towards disagreement.

For YS, the ability to quickly and accurately locate errors was found to be the most important aspect, in order to increase throughput and increase vehicle uptime. This was concluded both during the engine R&M focus group and the visit to the service workshop. Along with this, high predictability of failure is striven so that vehicles can be maintained and parts exchanged on planned occasions, making service a pro-active activity rather than reactive. The visit to the service workshop resulted in a few improvement suggestions regarding reparability and maintainability, all of them related to high accessibility for a more convenient working position. They were however presented as being unfeasible.

Reliance on modularisation was both observed on meetings and mentioned during interviews, most often from an assembly point of view, confirming it to be a company strength appreciated by many functions. The topic of modularisation was also raised in the survey to line assemblers through the statement “A high level of standardisation between engine variants is important for efficient assembly”, which assemblers agreed upon to a high extent, a mean of 5.0 out of 6 where 6 corresponds to full agreement. Standardisation was also selected by the respondents as (shared) second greatest advantage with the assembly process today. A foreman at the visited service workshop stated that standardisation between vehicles facilitates for mechanics too, for example when existing parts are incorporated in new products. This is interpreted as a positive attitude towards modularisation from the mechanic perspective as well. Ergonomics and part access were also mentioned by many interviewees from both DE and YS and on different organisational levels. However, the assembly sequence does not correlate with the procedure of part removal for service. So although the part access requirements from DE and YS may sound similar they can have different implications for the engine layout.

Both functions appear relatively satisfied with how their input is considered in the process for projects where they have taken an active part. Interviewees from both DE and YS mentioned there is a great difference between the first proposal they receive and the final version, meaning they are content with the output but must actively work for it. A project manager at DE has however noticed the production system is often seen as static by other functions and that new proposals are commonly compared to current products for assemblability, even for cases when the current solution is not ideal. The same view has also led to products developed over a long period of time being adapted to an obsolete production system.

During both focus groups, participants were asked to describe the perfect engine from their own perspective, with no feasibility constraints. This gave rise to a number of interesting comments, some of which are presented in Figure 5.2. Although many solutions are seemingly unfeasible, an interviewee with long experience of vehicle R&M stressed the importance of creating a common vision of a desired future state amongst stakeholders and then working to take small steps towards it, a process which might begin with this type of unconstrained brainstorming. The exercise also showed that wishes from the two functions are not always contradicting.

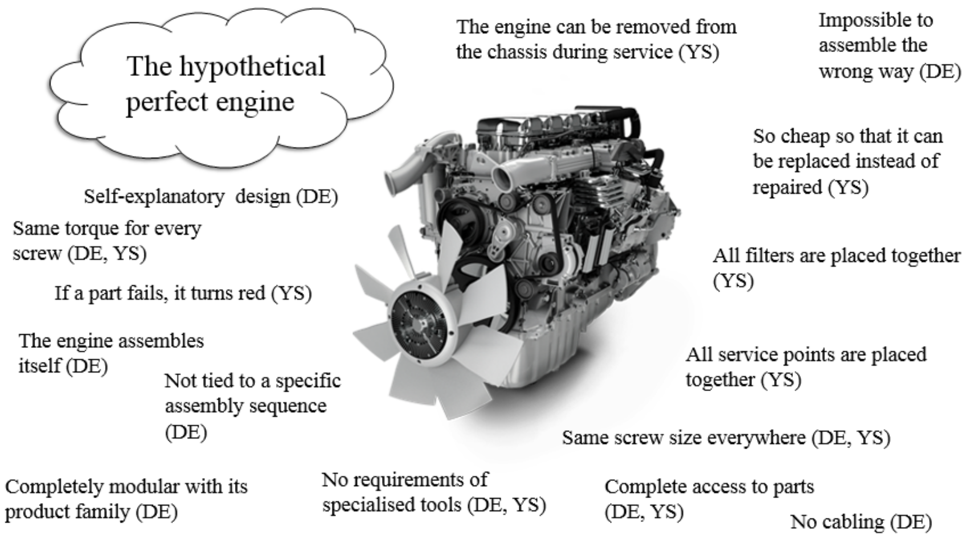

Figure 5.2 Compiled descriptions of a perfect engine, from focus groups and interviews with employees from the functions of engine assembly and vehicle service information (representing the engine R&M perspective).

5.2 Themes

When examining the collected data, five themes were derived under which the information in the categories of “Input” and “Process” was sorted. These are balancing requirements, communication of requirements, communication, concept and assemblability, reparability & maintainability.

As mentioned, the themes were also examined in the survey sent out to design engineers. Therefore the main part of the survey consisted of statements built from the groups of information which led up to the themes, as described in Section 3.5.2. The yes/no statements and open-ended questions also aimed to extend the knowledge within the themes, covering areas not yet specifically explored, i.e. treating the view of the NPD process. The questionnaire is presented in Appendix A.1, together with examples of how the statements were derived from the data, found in Appendix A.1.1.

The survey was distributed to 32 respondents, distributed as shown in Table 5.1, out of whom 19 replied. It cannot be traced who the respondents were, since the responses were collected anonymously to offer confidentiality. What is known is the working experience of the respondents, which ranged from less than a year up to 37 years in the company, as presented in Table A.2 in Appendix A.2.

Table 5.1 The sample of the design engineer survey.

Department	***Number of targeted design engineers***
Engine Body (NMBC)	5
Lubrication System (NMBO)	5
Valve Train (NMBW)	2
Crank System (NMDC)	4
Front End Accessory Systems (NMDF)	2
Valve System (NMDV)	2
Intake Components (NMGK)	5
Exhaust Components (NMGV)	7

Note: Department denotations are not acronyms of the full name.

The most interesting survey results for the purpose of the study will be presented in connection to their corresponding theme in the following section. A complete overview of the yielded results can be found in Appendix A. The theme “Concept” contained the view of what is a concept and how this can evoke disagreements and influence the work performed by the external stakeholders. This theme was however later omitted, since not as strongly connected to our scope. Nor did it provide any additional information in line with the research questions which was not already covered by the other themes. Each of the remaining four themes will be presented separately in the following sections.

The descriptive statistics recommended when dealing with Likert-type items (ordinal measurement scale) include median for central tendency and frequencies for variability (Boone Jr. & Boone, 2012). For this study, insights were sought regarding discrepancies or similarity in the responses rather than the median, which offers low resolution of the result. Therefore, analysis was focused on the frequency of responses.

In the following sections, the presented comments are both exact citations from the transcribed focus group material and also interpreted information extracted from the interview meeting minutes, where the latter activity can have been subject to the authors' perception and thus biased. All comments have furthermore been translated from Swedish to English, which can cause a loss of content, although they have all been verified in translated form by the informant. The source of the information is presented as the department within the function instead of the informant, to provide anonymity. To clarify, department denotations always begin with the two letters for the functions' superordinate function, e.g. DEP is a department within DE. For further understanding of the organisational context, the charts in Appendix C can be consulted.

5.2.1 Balancing Requirements

Several functions seem to be aware that design engineers must balance the requirements and that this is not an easy task. At the same time, they still look after their own demands and how these can be met to a greater extent. Both the engine assembly function and the vehicle service information function have initiated projects within their functions to design their requirements differently; DE by breaking down their production targets to more specific goals, and YS by quantifying their targets to better show what will be gained by meeting them.

Below is presented, in more detail, the findings related to the theme of balancing the requirements given as input to the design engineers, from the viewpoint of the key stakeholders. It contains subjects such as the responsibility of requirements balancing and what factors are assigned the most weight when performing the task.

5.2.1.1 Responsibility

It was expressed that balancing the requirements is a responsibility of the design engineer. This opinion was found both within DE and YS, and also shared at the managerial level of the design function itself as well as a design engineer.

> *"It is the design engineer's work to balance the demands, although we must try to understand their situation." (DEPB)*
>
> *"Design engineers receive many demands which must be balanced." (YSR)*
>
> *"It is the design engineer's work to, in cooperation with various functions, find a balance between the requirements." (NMB)*
>
> *"It is an important part of the design engineer's job to relate the design to the requirements coming in from different directions." (NMEO)*

As seen, the attitude differed somewhat depending on whose perspective was lifted; some stressed the importance of cross-functional cooperation whereas others rather seemed to label the design engineers as receivers of their input. Opinions were raised stating that one has to see to oneself, not to the needs of others, when creating the demands given as input to the NPD process.

> *"One has to do what one does best." (DEPB)*

> *"Factors to take into account include performance, durability (material properties), the purchase price, cost and serviceability, which all come in as requirements. Thus, the design engineers should have access to this information earlier in the process, and it should also include viewpoints from assembly." (DXT, former DEPB)*

It appears that collaboration between functions other than R&D is most common when involved parties want to strengthen their argumentation. If something is deemed more easily achieved by taking a common approach, e.g. between the functions of engine assembly and vehicle service information, these might discuss a joint approach in their standpoints. Otherwise the functions are rarely linked directly but rather connected through the design engineers. Steps to enhance the cooperation of these functions have been identified, where the cross-functional layout meeting Virtual Build is one example, but still design engineers are the ones taking the major cross-functional responsibility.

5.2.1.2 Priorities and Formulation of Requirements

Regarding priorities that affect the design decisions, different perspectives were presented. Some believed that impaired ergonomics has a great impact in trade-off situations while others mentioned legal regulations as the number one priority, closely followed by fuel consumption, which was also brought up by several interviewees. During the engine assembly focus group, the perception of the authors was that money is generally a more powerful argument than the Scania philosophy, where safety and ergonomics are top priorities. It has also been said that the features of the products is what should guide the design but that the awareness of this among the design engineers was perceived to be on various levels. Which priorities that holds the greatest influence is furthermore perceived to vary depending on where the project was initiated.

Connected to this, it was found that different perspectives exist regarding how the requirements should be presented in order to perceive that the demands are met to a higher extent. Opinions from several departments showed that it is believed to be easier to get through with demands if their effects are quantified. Personal contact was also mentioned to influence the design decisions.

> *"They (DE) have a strong voice since a change in the assembly can recoup so much money,* a *change that could make it more difficult for us (the service function)." (YSD)*

> *"A close contact between the engine assembly and the design engineers increases the ability to influence the process." (DXT, former DEPB)*

It was also presented that aspects such as ergonomics can be hard to substantiate since one cannot draw a number of what it costs. This was rather a matter of having a continuous communication in order to express the demands and comment on the design in order to change it, according to a manager at NM.

5.2.1.3 Method to Deal with Trade-Offs

Several representatives from the engine assembly function expressed that a design process taking manufacturing, including the aspect of assemblability, into consideration facilitates their work. Still, they showed understanding for the pressure this puts on both the design engineers and other functions involved in the NPD process, and are aware that trade-offs must be done. There were also indications of an awareness from the function of vehicle service information of the existence of conflicting requirements; "the design engineer ends up having functions pulling in different arms". They were also aware that there can be different main drivers in the projects, and that service cannot always be one of them. This perspective was also met in other interviews.

> *"The arguments from the assembly function sometimes weigh heavier than the input from the service function, since they can be more concrete about what the change will imply, e.g. if variants require certain solutions in order to be possible to produce – Scania must be able to manufacture their products." (TEEE, former YS)*

This mirrors the situation perceived by a design engineer, who mentioned that many requirements are communicated from both functions and that these are often contradictory, e.g. the assembly sequence desired from engine assembly and the placement of components preferred from the engine R&M. The same was expressed from a pre-production manufacturing engineer and from several other representatives.

> *"YS often work directly with the end customer and thus fast service is preferred in order to be profitable. But if the design solution brings a relocation within a standard assembly line in the production, and the ergonomics deteriorate, a trade-off must be done." (DXT, former DEPB)*

Many representatives additionally expressed that, according to their knowledge, no standardised method is in place to deal with contradicting requirements. This was for example noticed from both functions and also on project management level. It was furthermore expressed that a method would be appreciated.

> *"Transparency in the design process facilitate for all of us." (YDMM)*

> *"If one participates during the whole journey and has a dialogue about how events unfold, then it is easier to develop acceptance." (YSNA)*

5.2.1.4 Results from Design Engineer Survey

Synthesis of the discussions above led to the following statements in the questionnaire:

- I am expected to take a major cross-functional responsibility for meeting the received requirements
- Ergonomics is the factor with the greatest impact during the design process
- When balancing demands, I prefer supporting my decisions with requirements that can demonstrate positive financial results
- When balancing demands, I prefer supporting my decisions with requirements communicated to me via personal contact
- There exists a standardised method to balance between contradictory demands

It can be clearly seen that the view within the NM function is that design engineers are to take a major cross-functional responsibility for meeting the requirements received as input from different functions in the organisation. All respondents agreed to this statement, with 58 % answering “Agree” and 42 % “Somewhat agree”. This supports the data collected and presented above, where several functions expressed that it is the responsibility of the design engineer to balance the requirements presented to them.

The opinion about which factors to give priority varied, where ergonomics was regarded as important but also as only one out of many factors to consider. The responses confirmed this is a complicated task and indicated that there is no method in place to handle the balancing of requirements, instead it rather comes down to the individual design engineer or drivers of the project. The distribution of the answers are presented in Figure A.1 (Appendix 0) and extractions the free text option to the choices “Somewhat disagree” and “Disagree” are presented in Table 5.2. All responses are found in Appendix A.2.

Table 5.2 Excerpts from the free text answers to the statement "Ergonomics is the factor with the greatest impact during the design process".

Respondent	*Free text answer*
R1	/.../ Ergonomics (a requirement from the engine assembly) is extremely important and something we should take into account. But there are many other demands which are also important that we must consider when developing a product. For example, we cannot release a product that does not meet the requirements of strength but is ergonomic to assemble. /.../
R5	Manufacturability, performance, functionality, reliability (strength etcetera), assemblability and service precede ergonomics, but ergonomics is partly/largely included in the terms assemblability and service but unfortunately we do not design for ergonomics, it's more like a "bonus". We assume that the assembly and service solve heavy lifting etcetera with lifting tools etcetera.
R12	Performance/consumption impact - right to the end customer
R14	/.../ What is the most important factor varies depending on the project, often factors such as robustness, fuel consumption and price are highly prioritised.
R16	The functionality is always the most important, then one has to compromise sometimes.

When balancing the requirements, design engineers prefer those that can show a positive financial result. Requirements communicated in person also seem like arguments used to support design decisions. However, the responses vary, see Figure 5.3, indicating that project output is influenced by individual way of working.

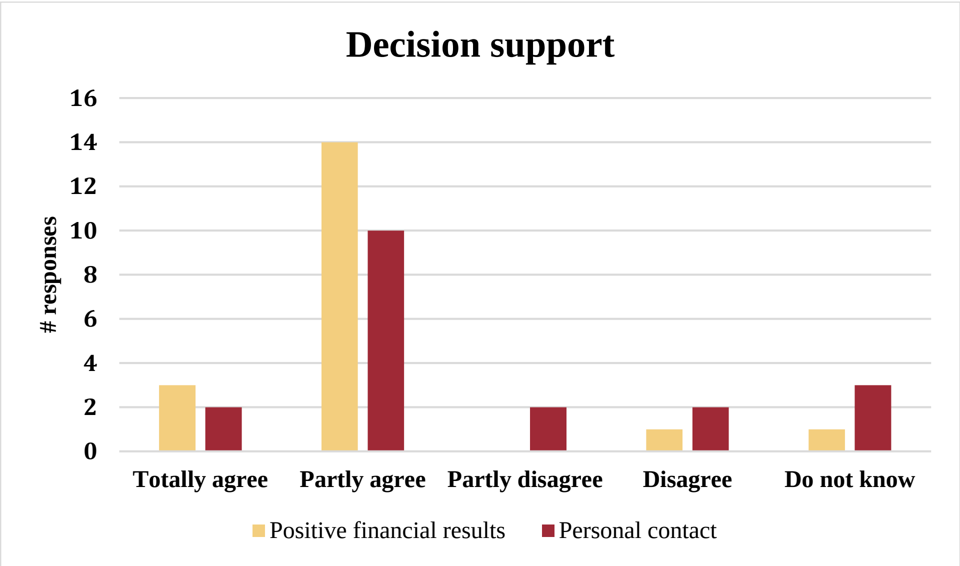

Figure 5.3 The distribution of responses to the two statements "When balancing demands, I prefer supporting my decisions with requirements that can demonstrate positive financial results" and "When balancing demands, I prefer supporting my decisions with requirements communicated to me via personal contact".

The last statement, “There exists a standardised method to balance between contradictory demands”, yielded responses distributed over the entire range of the scale, as presented in Appendix 0. A remarkable result was that a high number, 26 %, of the respondents chose the option “Do not know”. This corresponds to five responses where the working experience of the respondents ranged from 0.5 to 21 years. The same goes for those respondents who answered “Agree” or “Somewhat agree”, six in total, where the range of experience stretched from 4 to 10 years. Free text answers yielded mixed results, as seen in Appendix 0, where some responded with improvement suggestions and other referred to common sense as the best method. Hence, this seems not to be related to how used one is to work in accordance with the principles applied in the R&D departments and the institutionalised structures in the company. Instead, the inconsistency in the responses seems to mirror the individuals’ perception of the work tasks and their (individual or group-wise) use of supporting tools available.

5.2.2 Communication of Requirements

Input seems to reach the design engineers via several channels with the common denominator of involving personal contact, rather than formalised routines like documents or standardised digital tools (at least this is not presented as the most important way of transferring information about expectations and demands, e.g. DFA and SES were seldom mentioned). The engine assembly function seems to affect the NPD process and to participate to a high extent. The vehicle service information function is perceived to be more absent, though seen to increase their involvement lately. This is regarded as positive and also to have resulted in increased influence on the process output. The requirements reaching the design engineers are also formulated on varying level of detail, depending on when and how the information is transferred, and what are the working procedures within the departments. The requirements thus often have to be further discussed in person, and there are many ways of solving unclear issues. What does not seem to be in place is a routine to facilitate the feedback about how requirements were considered and why specific ones were not met in the development process and incorporated into the final design.

Below is presented, in more detail, the findings related to the theme of communication of requirements, from the viewpoint of the key stakeholders. It revolves around how the different functions, the engine assembly function and the vehicle service information function, communicate their demands to the R&D function. This includes both on what level requirements are transferred, what channels are being used and how these are influencing the design process.

5.2.2.1 Personal Contact and the Level of Influence

The information exchange between design engineers and the assembly function mainly takes place via meetings, according to a senior manager at engine development, which is a view shared by a development engineer. Communication between the vehicle service information function and other functions are also mainly undertaken via mail, telephone calls or visits. Requirements and design propositions are thus transferred through personal communication, often informal, rather than through formalised documentation. An exception is formalised deviation reports, which are communicated through the follow-up report administration system (called FRAS) directly between involved parties. So, the situation appears to be that information transfer to a large extent takes place directly between project team members, without being documented or lifted to project level. Hence, project managers at XP and managers on a high level in the organisation cannot pinpoint exactly where input enters the process which can appear a disadvantage, but a project manager confirms the importance of personal contacts.

> *"Documents and systems are useful tools for communicating, but can never become a substitute for the contact occurring via personal relations." (XPB)*

While DE can always provide input to the process, they however state that output from the early design process is not always shared with them, indicating a lack of transparency in earlier phases. Still, they are considered to have impact on the NPD process and share information about what they expect and wish for, and can also present effects of what will happen if these are not met. This view is supported by a project manager who perceives those at the engine assembly function as being active in the development process.

The continuous communication between the engine assembly function and design engineers is confirmed and appreciated by the interviewees. On the contrary, the vehicle service information function is seen as more passive by several representatives. A design engineer believes that they are noticing problems in later stages in the process, but has also identified a change in their way of working; moving towards a higher level of involvement.

> *"YS now seems to take a more active role in the development process." (NMEO)*

This trend has also been noticed by project engineer and managers, as well as by people within the YS, who experience that with earlier involvement in the process, their propositions are taken into consideration to higher extent.

> *"Earlier, the case was often that production were the ones deciding, which was unbeneficial for YS." (YSNB)*

But even though the function seems to be better integrated and more represented in the NPD process, they are still regarded as less personally engaged in the projects than is the engine assembly function.

5.2.2.2 Level of Communicated Requirements

Design engineers working on a detailed level never describe a formalised method for how and when information enters the process. Requirements are communicated both as documented guidelines, such as SES and the DFA checklist, as formal documents, such as AD and PDf, and through personal communication. The latter is the most commonly mentioned method, especially for detailed requirements. Both during the focus group and interviews with engineers from DE, the level of detail in the formulation of requirements was discussed. The general opinion appears to be that requirements must be interpretable on part level so that design engineers can make use of them directly, which is today assured through personal communication rather than through documentation.

The requirements communicated from DE have historically been more explicitly formulated on a general level than a project specific, although ongoing improvement initiatives aim to counteract this tendency. A project manager at DE shared the perception that their involvement in the yellow arrow has been poorly managed, and argued it is their own responsibility to formulate the requirements on a level easier to translate into the design. This view is supported by a project manager at XP.

> *"Our generic demands do not communicate well what we want." (DEPA)*

> *"The requirements now are on standard form; with wishes like "no poorly designed assembly activities" and "takt time of 90 s". These requirements should be broken down further to be used in the design, in order to ensure the fulfilment of the general requirements." (XPB)*

This issue was also yielded from several representatives in connection to the level of the communicated requirements coming from YS. A project manager who shared this view during the interview has though lately experienced a positive change in their way of working.

> *"Lately, YS has started to communicate the requirements in a specific and clear manner. Still, the difficulty for relatively small cross-functions to fully participate in all projects may result in that only general requirements are communicated." (XPB)*

Some detailed formulations have been observed in documentation from both DE and YS and it also appears that employees at both functions are confident with drawing up detailed requirements or propositions, once they have a detailed product to evaluate. Different perspectives on the topic was however discovered, where some expressed the wish to earlier communicate clearer goals and stated that they have a better overview of the details than the objectives on a high level. On the other hand, it was said that requirements should not be on a too detailed level, since that is the work of the design engineers.

5.2.2.3 Results from Design Engineer Survey

Above synthesis led to the following statements in the questionnaire:

- Requirements from DE are mainly communicated through personal contact
- Requirements from YS are mainly communicated through personal contact
- Requirements communicated from DE have a high level of influence on the design
- Requirements communicated from YS have a high level of influence on the design
- If YS is represented during cross-functional layout meetings, their requirements will be met to a higher extent
- The production targets communicated by DE are hard to make use of in detailed designs
- The product targets communicated by YS are hard to make use of in detailed designs
- Communicated requirements often need to be further specified with the initiating party
- The project definition (PDf)/object definition (ODF) is used in the design process
- I find non-project specific “requirement lists” (e.g. DFA and SES) to be valuable tools in my design process
- Routines exist to provide feedback to the initiating demand provider of the requirements that cannot be met in the design

Additionally, it provided the basis for the following yes/no statement:

- More explicit requirements at component level would facilitate my work

And the open-ended question:

- At what stage of the NPD process would you like to receive detailed requirements from DE and YS?

The survey results showed that personal contact indeed is an important aspect during the design process, where nearly all the respondents agreed or partially agreed to the statement that requirements mainly are communicated this way. Regarding the impact, the collected data showed tendencies of DE being the more influential function during the development process; considered to communicate their demands louder and influence the design to a larger extent. The result however did not show a clear difference in influence, see the responses presented in Figure 5.4. The almost uniform answer, supported by 90 % of the respondents, was that if being more present, requirements from YS are met to a higher extent.

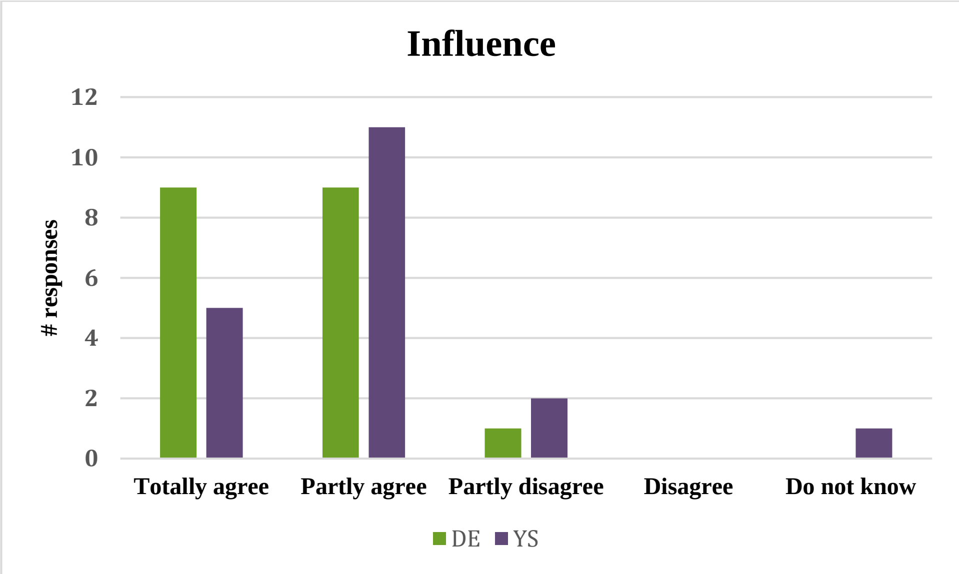

Figure 5.4 The distribution of responses to the statements "Requirements communicated from DE have a high level of influence on the design" and "Requirements communicated from YS have a high level of influence on the design".

Regarding level of detail of communicated requirements, findings from the data collection indicated that production and product targets used as requirements today are on a high level and often not project specific. This was partly confirmed in the survey where as many respondents agreed to some extent as somewhat disagreed to the statement that the production targets are hard to relate to their designs. The product targets transferred from YS are seen to be harder to make use of in detailed designs, but also yielded scattered responses as presented in Figure A.1. The questionnaire revealed that requirements often need to be further specified with the initiating parties and the preferred way of doing so is to meet in person, thus having the opportunity to verbally brief, discuss and deepen the understanding of them (see A.2.3). It was also seen that there is no consensus about what level is preferred from a designer's point of view. The prevailing view is that more evident requirements at component level would facilitate the design process, but the opinion is not shared by 26 % of the respondents. Opinions about when the more specific information should be received as input also differed among the respondents (see Table A.8 in Section A.2.3).

No clear conclusion could be drawn regarding the use of the PDf/ODF documents in the work performed in the targeted design departments, nor in the use of other tools, where 58 % answered that the available "requirement lists" (DFA and SES) were useful or somewhat useful in their design process. The clarifying free text answers of those who responded either "Agree" and "Somewhat agree" (found in Table A.6, Appendix A.2.1) however indicated that the respondents only applied

SES Design as no one mentioned DFA. Hence, the survey confirmed the picture that the tool is mainly well-known and used within DE and not institutionalised at NM.

Two respondents fully agreed to that a routine exists to provide feedback to the requirement initiator, responses which stood out from the rest. The years of experience as design engineers at Scania of those two respondents were 4 and 37 respectively. Again, the level of agreement does not seem to be related to how used one is to work in accordance with the principles applied in the R&D departments, but rather to the individuals' perception of their or their departments' way of working (e.g. if close communication is perceived as a routine by the employee) Still, note that nearly 60 % of the responses indicated some kind of routine exists – a view contradicting what was found within the organisation during the interviews with function representatives.

5.2.3 Communication

The engine assembly function is active already during concept development, providing input to the AD. During the development process, the design engineers seem to keep in close contact with the function, receiving design guidance or indications if the design is poorly adapted to the production system. The existing knowledge should be used in order to minimise waste and recurring implications but Lesson Learned, which aims to retain learnings within the organisation, is not perceived as a tool commonly applied by everyone. A rather new way of working is Virtual Build meetings, which provide a forum to discuss the design from different viewpoints. As misunderstandings constitute a risk to the projects, it is important that communication is clear during the development process.

Below is presented, in more detail, the findings related to the theme of communication. In contrast to that of requirements, this deals with topics such as attitudes towards the information transfer and available facilitators to share information between the functions.

5.2.3.1 The View of Cooperating Activities

A common view appears to be that DE works actively during concept development, e.g. by providing input to the assignment directive. A project manager at YD had the experience they are also actively participating during the PPM, which contradicted a project manager's view from within DE, who said they are present during these meetings but that focus rather is on collecting information shared by the other functions than on providing information.

Starting in the developing phase, layout meetings coordinated by NM are held. The impression is that both DE and YS are attending these. Representatives from NM seem to appreciate early input from the production, believed to contribute with useful experience. The output from the early design process is however not always shared the other way around. A manager at DE shared the view that the function is involved early on, but expressed that there is less cross-functional cooperation during these stages. A possibility for DE to earlier start their close cooperation with design engineers is seen as beneficial, since the NPD process is believed to be positively affected by their early involvement.

The cooperation between the functions DE and NM is expressed to work well due to a close communication. According to a manager at DE, the relations to other functions in the organisation are generally good, but the relation to the design function was specifically brought up during the interview and no negative attitude towards design engineers was observed. The view of good relations was also found to be shared by others within DE, even though it was sometimes expressed in terms of what positive outcomes the relations yield.

> *"Sometimes the reaction can be somewhat grumpy, but if the design engineers get early input, the lead time will be reduced in every following stage." (DEPA)*

The contact between NM and DE is also initiated when input is needed to support the design process. This is further substantiated by comments from other representatives, whose experiences are that DE offer support during the projects.

> *"Production is normally actively involved in the development process." (NMEO)*

> *"The engine assembly function reviews the design and provides feedback during the design process." (XPB)*

5.2.3.2 Sharing of Competences and Experiences

Building on previous experience in projects is encouraged, e.g. early consultation of the knowledge bank during the design process to consider the existing knowledge and previous experiences regarding the technologies available. Lesson Learned is an institutionalised method in the NPD process to learn from previous deviations so as to not encounter the same issues twice. A project manager at XP noticed that when Lesson Learned is consulted early on during product development, it serves as a tool to draw attention to possible risks, hence reducing the number of recurrent problems. Despite this seemingly positive outcome, several representatives from different functions stated that it could be used more than today; some departments have successfully adopted the tool, whereas others have not done it equally well.

The VB meetings share resemblance with the layout meetings performed by the departments of NM, and are held at the initiative of the engine assembly function. A responsible manager for the meetings argued that representatives from YS are invited and should be present during these.

> *"They (YS) are always invited, but not always attending." (DEPB)*

From the observation of one such meeting it was seen that sharing design propositions, e.g. solutions to potential assembly problems, was encouraged and comments were considered and discussed. Several of the present parties were very active during the session, and the atmosphere was friendly.

Despite a seemingly well-functioning meeting culture, a representative from DE highlighted miscommunication as a risk factor negatively affecting the quality of the NPD project output. Similar opinions were shared by project managers at XP, saying that deviations are not communicated properly and thus negatively affect the information transfer information. Since the deviations are prioritised on the basis of how critical they are, this must be clearly transferred from sender to receiver.

5.2.3.3 Results from Design Engineer Survey

Above synthesis led to the following statements in the questionnaire:

- The input received from DE in the yellow arrow facilitates the design process
- I experience a well-functioning support from DE throughout the design process
- Lesson Learned is an efficient tool to counteract earlier problems being experienced again
- I appreciate Virtual Build as a work method to receive cross-functional feedback on my design solutions
- Misunderstandings in the communication are frequently experienced in projects

Additionally, it provided the basis for the following yes/no statements:

- I prefer to have a continuous contact with other functions during the project
- I prefer that design decisions are taken at a few major milestones

And the open-ended questions:

- How would you like to receive requirements from DE and YS in order to work with them in the best way? (verbally, written, digitally, etc.)
- In what way do you think a cross-functional collaboration favours the design process?

The majority seem to regard the input received from DE early in the design process as useful. However, the experienced support throughout the process vary, where five responses were in favour of the provided support, whereas the same amount of respondents chose the option “Somewhat disagree”. It appears a continuous communication between NM and the other functions is preferred to a greater extent than taking decisions at a few milestones (see Appendix A.2.2). The information can flow in form of written documents, as digital files, during layout meetings, as face-to-face meetings or via e-mails or telephone calls. No channel seems to be more preferred than another, it rather depends on when in the process information is transferred, what is being transferred and who is involved (see Appendix A.2.3).

The ways of working in order to continuously learn and share experiences and knowledge, Lesson Learned and VBs, are not perceived in similar ways among the design engineers. Where some regarded them as useful, others either did not know or did not approve of them. A positive attitude towards a cross-functional working is though apparent; deemed to shorten lead times and lead to wiser design decisions early on, thus enhancing the quality of the products (as seen in Appendix A.2.3). In contrast, it was confirmed that misunderstandings are commonly experienced.

5.2.4 Assemblability, Reparability and Maintainability

The experience of the design engineers appears to strongly influence how the assemblability aspect is incorporated into the design. At the same time, DE is perceived to possess the knowledge about what needs to be done in order for designs to fit well to the production system without affecting the ergonomics negatively. It does not seem that design solutions are assessed for assemblability by using customised software, but rather ensured by keeping a continuous contact with DE, whom are also coordinating the test assemblies to be performed. Reparability and maintainability are not discussed as much as is assemblability, but YS is working to further include the aspects early on in the design process.

Below is presented, in more detail, the findings related to the theme of assemblability, reparability and maintainability from the viewpoint of the key stakeholders. It revolves around what impact experience has in the design process, if software is used to support the design solutions and the responsibility issue for ensuring DFA/DFS.

5.2.4.1 Designing for Assemblability

Several representatives shared the view that the experience of the design engineer is important when ensuring the assemblability in a design, e.g. mentioned from representatives from the engine assembly function, design and project management.

> *"The balancing between requirements are often performed through judgements rather than hard facts. Whether the decision makers (e.g. design engineers) know the effect of the decision probably differ from individual to individual." (DEP)*

> *"An experienced design engineer can notice assemblability implications already by observing a test assembly, whereas others miss them." (NMEO)*

> *"The ability to relate the design to the overall demand picture is mainly based on the experience of the individual (the design engineer)." (XPB)*

Thus, the experience seem to affect the ability to identify potential problems and solve them pro-actively, meaning DFA is primarily assured by experience. Guidance is also obtained by interpreting the information received at meetings, according to a design engineer from NM.

It was said that assemblability is not a subject discussed much at R&D during concept development and that there is not sufficient competence to do so. This must instead be more distinctively communicated from DE, according to an internal source at the function. In the other end of the spectra is the engine assembly function, where assemblability is said to influence every aspect of their daily work. Their perception is that they sometimes receive designs with a low level of assemblability, with the justification that products similar to those are already produced.

> *"Even though we handle this today, it does not necessarily mean it is well adapted to the production." (DEPA)*

The function is perceived by others as active in ensuring attention is drawn to the assembly process, by being present at layout meetings and reporting to NM if designs are "clearly out of line". They are also the ones responsible for ordering the tests performed in the projects; which tests to conduct and when. These are undertaken in order to visualise deviations and assembly risks, but how this is organised seems to vary between the projects.

> *"The process of test assemblies relies heavily on the relation between the product engineer and the design engineer." (DXT, former DEPB)*

5.2.4.2 Designing for Reparability and Maintainability

Several representatives expressed requirements coming from DE and YS as opposing, in the sense that service mainly is performed from below whereas assembly activities generally are accomplished from above the engine. This is for example illustrated by a jocular comment made by a project manager within DE.

> *"If the engine was to be perfectly designed for the assembly process, then service cannot be taken into consideration at all, since we almost always want different things." (DEPA)*

The attitude towards the requirements drawn by YS seem to have changed and there is a greater understanding of why they should be communicated and treated in the design process. However, both NM, which receives and work with the requirements, and voices within YS, raised the issue that a difference exists between how the design process includes the aspects of reparability and maintainability compared to that of assemblability.

> *"The vehicle service information function feels neglected." (NMEO)*

> *"In my view, production is a couple of years ahead of us in their way of working, both when it comes to chassis and engine." (YSR)*

A representative from YS believed that the aspects of reparability and maintainability are actively supported by YS throughout the process. Ergonomics is however an issue not gaining as much focus. The shared view is that the level of ergonomics in service workshops is low, but that other drivers in the project can be prevailing. However, a manager at NM expressed ergonomics is being considered.

> *"When initiating a new project, there are eight focus areas. Out of these eight, only a couple are project drivers, hence not always reparability and maintainability." (YSR)*

> *"Scania can, and tries to, develop and improve the way of designing for an ergonomic service procedure." (NMB)*

In the same way that activities initiated from DE seem dependent on who is involved in the project, assignments of digital tests performed to ensure disassemblability are often assigned to test leaders already known to the person ordering the test.

5.2.4.3 Results from Design Engineer Survey

Above synthesis led to the following statements in the questionnaire:

- My experience is the most important factor when assessing the level of assemblability
- DE has the main responsibility to ensure a high level of assemblability of components
- I use software to ensure the assemblability of my design solution
- How the work with physical and digital test assembly/disassembly is carried out in the projects depends on whom I work with

Additionally, it provided the basis for the following yes/no statements:

- Assemblability is actively discussed at R&D
- Designing for repair and maintenance is actively discussed at R&D

Experience clearly appears to influence the designer's work with 73 % of the respondents either agreeing or somewhat agreeing to the statement. The three respondents who disagreed were further seen to have relatively short experience (0.5, 3 and 4 years respectively) as design engineers at Scania. Whether or not it is instead the responsibility of DE to ensure the assemblability of the designed parts, is unclear, the responses to that questions being scattered as seen in Figure A.1 (Appendix 0).

Assemblability is seen to be a subject discussed at R&D; in total 16 out of 19 respondents said this is the case, the corresponding number for repair and maintenance being 14. No other software than CATIA was however mentioned as used to support the design for assemblability and more than half of the respondents chose the option "Disagree" to the statement concerning usage of software. The tests performed during the development process to ensure the design is able to manufacture and service, are seen to be dependent of the people involved, the statement being fully agreed upon by 16 % and getting some agreement from an additional 42 % of the respondents. All results are presented in Appendix A.2.

6 Results

In this chapter, the final results of the study are presented, connected to the research questions – one section dedicated to external stakeholder expectations and one to critical factors affecting their fulfilment. The results build on the general findings previously presented in Chapter 5.

6.1 External Stakeholder Expectations

All of Scania's functions are ruled by the same three core values which in this study were broken down to a set of high-level objectives, for increased clarity and applicability. The seven high-level objectives identified in the study, based on collected data, are presented in Figure 6.1 together with the core values of Scania. Each objective is more closely described in the following section and the set will be used to demonstrate the value of fulfilling the external stakeholder expectations identified by the authors. While being more specific than the core values, all high-level objectives are however still generically formulated to be applicable not only to this study but to all of Scania's core processes: product development, sales, order-to-delivery and service delivery (Scania CV AB, 2015d).

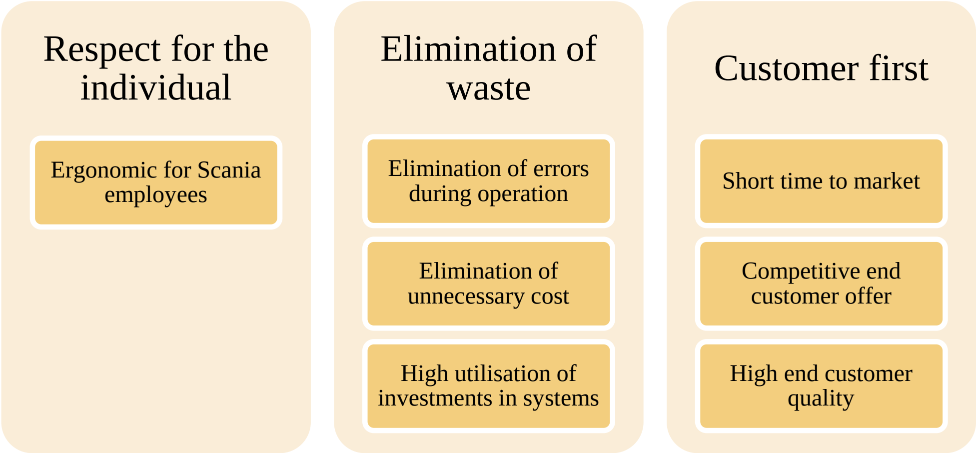

Figure 6.1 The external stakeholder expectations all create value for at least one of the seven identified high-level objectives, which can be sorted under the three core values of Scania (Scania CV AB, 2015a).

6.1.1 High-Level Objectives

Ergonomic for Scania Employees

This objective covers an ergonomic working situation for all Scania employees; in Södertälje facilities and on other sites. While all operations included in work descriptions should be ergonomic, focus is on those performed with high frequency. An ergonomic working environment is part of the Scania House top priority "Safety/Health/Environment", see Figure 2.1. It is also covered by the company core value "Respect for the individual". As the Scania priorities and core values are consistent with those advocated in lean theory, the objective is not merely company-specific but an important part of lean philosophy.

Elimination of Errors during Operation

Errors during core process operations lead to rework, scrap and, if occurring during production, stops on the takted line which ultimately affects productivity and profitability. This objective is directed towards internal errors, i.e. those not perceived by the end customers but corrected internally before delivery of product. All Scania sites are considered internal, including the globally distributed workshops. Elimination of errors is a cornerstone in lean thinking and a widespread goal at Scania, promoted through principles like "right from me". While already well-established in the production system, it can be argued to be equally important for all operations undertaken by the company.

Elimination of Unnecessary Costs

Efficient processes must not yield costs which can be avoided without process quality decrease. The objective of elimination of unnecessary costs is related to inefficient working processes (high personnel costs), inefficient logistics processes (high inventory costs) or inefficient production processes (high material or work-in-process costs) while unnecessary costs due to errors are not included. Costs which are incurring without creating value are regarded waste and this objective is consequently derived from lean thinking.

High Utilisation of Investments in Systems

System investments are necessary to maintain and develop high-performance production sites and workshops. However, investments must pay off through high utilisation in order contribute to profitability or else expenditures are wasted. Systems which can be used for a great range of products are for example considered more beneficial than investing in individual solutions for each new addition to the product portfolio, which leads to high capital costs for the same value adding capacity. This objective is achieved by finding the right balance between standardisation and flexibility. Taking maximum advantage of equipment, tooling and systems is expressed as a goal on functional level at Scania, indicating relevance of this objective. Lean product development theory also states that utilisation of existing systems can reduce development time.

Short Time-to-Market

Short time-to-market includes the entire process between idea generation and launch of a product; concept development, product development, preparation of aftersales services and production ramp-up. It is closely connected to utilisation of existing resources in new projects, e.g. knowledge, production equipment or product platforms. The objective targets speed to market; the ability to provide customers with fresh, new solutions in the rapidly changing market environment. Achieving short time-to-market is at Scania regarded as a means to secure competitiveness. Also, it is a pre-requisite for first mover advantage, should the company opt for that strategic approach.

Competitive End Customer Offer

A competitive end customer offer means the right product must be offered to the customers at the right cost. This objective focuses primarily on the right product part. To serve a diverse customer basis with right products, the company must either have a large product portfolio, offer customised products or a combination of the two. Additional offers, such as services or additional features, are also included in the customer offer. Having a competitive customer offer is a necessity to compete on the multi-player market. The relevance of this objective is also supported by the strong customer focus of both lean theory and the Scania philosophy.

High End Customer Quality

This objective targets end customer quality, i.e. quality perceived by the customer. Hence, errors corrected in-house are not included if not deemed to affect the robustness of the product, once sold and used. Apart from the quality of the product itself, the objective also covers quality created during the product lifetime, during usage. This can include value adding features, customer service and additional services bought by the customer but not utilised directly. Quality and end customer value are cornerstones of the Scania philosophy, quality also the second highest priority in the Scania House, pointing to the relevance of this objective not only to companies in general but to Scania in particular. By extension, this objective also contributes to the preservation of Scania's brand image.

6.1.2 Presentation of the Identified External Stakeholder Expectations

The data collection generated 197 quotes or comments regarding expectations on the output of the process, and all but five are related to one or more of the above presented objectives. From the data, a total of 22 external stakeholder expectations were identified, most of them relating to only engine assembly or engine repair and maintenance but a few applicable for both areas, as listed in Table 6.1. The external stakeholder expectations are not locked to one solution only but can often be fulfilled in several ways and by various functions. For example, easy differentiation of parts for assemblers can be achieved by making variants clearly distinct visually, with different colours or geometrical features. It can also be achieved by installing a pick-to-light system so that assemblers get a signal to which variant to pick, making it easy to do right even though the part variants themselves are hard to distinguish.

Despite the term "stakeholder *expectations*", stakeholders did not always express expectance of their fulfilment but merely a wish for them to be fulfilled. Still, all external stakeholder expectations have potential for creating value for Scania as seen in Table 6.2, where the connections between stakeholder expectations and high-level objectives are presented. Knowing the value of fulfilling external stakeholder expectations facilitates communication of related requirements and their importance during projects. Requirements and targets connected to the expectations are frequently put against each other in trade-off situations during the development process and the value of each must then be understood and appreciated in order to make deliberate decisions.

Table 6.1 External stakeholder expectations identified in the study. Only documentation directly referred to during interviews, focus groups or observations is included.

External stakeholder expectations with clarifications	***Information source***
Engine assembly	
No risk for assembler injuries with planned assembly procedure *Injuries can be immediate, e.g. cuts, or accumulating over time, e.g. back problems*	Participant observation: assembly line Documentation: SES Production
Engine layout and parts are adapted to standardised assembly operations *Includes both manual and automated operations on the assembly line as well as supporting logistics operations*	Interview: DXT (former product engineer DEPB) Engine assembly focus group: project manager DEPA, product engineer DEPB, process engineer DEPG and technical product manager YDMM Participant observation: assembly line Line assembler survey: question 12, 13
Parts are easy to position, insert and fasten *Includes intuitive positioning, insertion and fastening*	Engine assembly focus group: Product engineer DEPB and technical product manager YDMM Participant observation: assembly line
Low sensitivity of parts to damage during assembly *Damage due to deviations in production system or assembler operations*	Interview: development engineer NMEO Participant observation: assembly line
An efficient solution for manual or automated quality assurance on the assembly lines *E .g. manual or automated visual inspection to ensure no quality deviations exist of parts or assembly jobs*	Interview: project manager DEPA Participant observation: assembly line (incl. expressed by a process engineer)

An efficient solution for manual or automated part assurance on the assembly lines *E.g. differentiation through colour-coded parts or matrix code scanning to ensure the correct articles are assembled*	Engine assembly focus group: technical product manager YDMM Participant observation: assembly line
Avoidance of assembler jobs with restricted vision *Includes quality assurance and situations where good vision require a non-ergonomic working position during assembly*	Participant observations: assembly line and Virtual Build
Engine layout and parts enabling a well-balanced assembly line For given assembly sequence	Engine assembly focus group: product engineer DEPB and technical product manager YDMM Participant observation: assembly line Line assembler survey: question 14
No duplication of jobs with planned assembly sequence *E.g. temporary removal of one part to access another*	Participant observation: assembly line Line assembler survey: question 14
Good alignment between product and planned production system *Refers to the desired future state of the production system upon product introduction*	Interview: manager DEPB. Engine assembly focus group: product engineer DEPB, technical product manager YDMM
Engine assembly and engine R&M	
Utilisation of product platforms to as high extent as possible *Using existing parts means that e.g. part life length has been tested, employees are familiar with the parts and existing tooling can be used*	Interview: technical product manager YDMM Engine assembly focus groups: project manager DEPA, product engineer DEPB, process engineer DEPG and technical product manager YDMM Participant observations: assembly line, service workshop Virtual Build and PPM Line assembler survey: question 12
A minimum of part variants over current product range *For engine assembly: over product range currently in production. For engine R&M: over product range currently in use*	Engine assembly focus groups: project manager DEPA, product engineer DEPB, process engineer DEPG Participant observation: service workshop
Low product complexity for given level of functionality *While complexity is not desired, it often follows increased functionality and an appropriate balance must be sought*	Engine R&M focus group: manager YSNB, consultant YSR

Engine R&M	
Easy access to parts frequently maintained *Includes ergonomic access*	Interviews: DXT (former product engineer DEPB), manager NMB, project engineer TEEE (former YS), development engineer YSNB and consultant YSR Engine R&M focus group: consultant YSR Participant observation: service workshop
Easy access to parts frequently repaired or replaced *Includes ergonomic access*	Interviews: DXT (former product engineer DEPB), manager NMB, project engineer TEEE (former YS), development engineer YSNB and consultant YSR Engine R&M focus group: consultant YSR Participant observation: service workshop
Clustering of parts frequently repaired or maintained together *When parts are clustered, service jobs can be streamlined and engine interference is minimised*	Interview: manager NMB Engine R&M focus group: mechanic YSD, manager YSNB
Engine layout and parts are designed for intuitive R&M jobs *Intuitive jobs make for faster and more accurate service*	Interview: consultant YSR Documentation: General targets and requirements of the vehicle service information function
Good fit of product with current service procedures	Interview: consultant YSR Participant observation: service workshop
R&M jobs can be performed with standard workshop equipment and tools *The variety of jobs being performed at service workshops makes many specialised solutions unfeasible*	Engine R&M focus group: manager YSNB Participant observation: service workshop
Predictable or dynamically updated maintenance intervals	Interview: project engineer TEEE (former YS), consultant YSR
Predictable or dynamically updated part life length *E.g. that information of current wear status is available so that replacement can be planned*	Engine R&M focus group: development engineer YSNA, consultant YSR
Engine design supports systems for quick and accurate diagnostics *Diagnostics adds non-value adding time to R&M jobs*	Engine R&M focus group: mechanic YSD, development engineer YSNA, manager YSNB, consultant YSR Participant observation: service workshop

Table 6.2 Connections between external stakeholder expectations and high-level objectives.

External stakeholder expectation	***Ergonomic for Scania employees***	***Elimination errors during operation***	***Elimination unnecessary costs***	***High utilisation of investments***	***Short time-to-market***	***Competitive end customer offer***	***High end customer quality***
No risk for assembler injuries with planned assembly procedure	Enhanced assembler ergonomics						
Engine layout and parts are adapted to standardised assembly operations		Assembler experience reduces risk for human errors	No setup time between variants or off-line operations	Reduced investments with lower PS flexibility requirements	New introductions require less extensive PS preparations		
Parts are easy to position, insert and fasten	Ergonomic part handling	Reduced risk for human errors Smoother introductions					
Low sensitivity of parts to damage during assembly		Less scrap Less rework					
An efficient solution for quality assurance on the assembly line	Enhanced assembler ergonomics	Higher reliability in quality assurance	Minimal time spent on on-line quality assurance	Efficient utilisation of IPV equipment			Higher reliability in quality assurance
An efficient solution for part assurance on the assembly line	No conflict with assembler ergonomics	Higher reliability in part assurance	Minimal time spent on on-line part assurance	High utilisation of part assurance equipment			

Table 6.2 Connections between external stakeholder expectations and high-level objectives (continued).

External stakeholder expectation	***Ergonomic for Scania employees***	***Elimination errors during operation***	***Elimination unnecessary costs***	***High utilisation of investments***	***Short time-to-market***	***Competitive end customer offer***	***High end customer quality***
Avoidance of assembler jobs with restricted vision	Enhanced assembler ergonomics	Easier to do right for assemblers					More reliable quality assurance
Engine layout and parts enabling a well-balanced line			Less idle time for assemblers	High and even PS utilisation			
No duplication of jobs with planned assembly sequence		Reduced error risk	No double-handling	Higher throughput			
Good alignment between product and planned production system		Fewer errors during or after introduction	No costly last-minute solutions	Reduced time for PS verification and ramp-up			
Utilisation of product platform to as high extent as possible	Increased possibilities for developing ergonomic solutions	Employee experience reduces error risk		The same PS can be used for a variety of products	Reduced time for product development	Diverse product portfolio	Employee experience build-up can increase quality
A minimum of part variants over current product range		Reduced risk for picking errors	Reduced inventory costs	Reduced PS flexibility requirements			

Table 6.2 Connections between external stakeholder expectations and high-level objectives (continued).

External stakeholder expectation	*Ergonomic for Scania employees*	*Elimination errors during operation*	*Elimination unnecessary costs*	*High utilisation of investments*	*Short time-to-market*	*Competitive end customer offer*	*High end customer quality*
Low product complexity for given level of functionality		Fewer operations which can go wrong	Easier trouble-shooting during service No time spent on excessive PD activities	No efforts during PD is spent on excessive features			More robust product as fewer things can fail
Easy access to parts frequently maintained	Enhanced mechanic ergonomics		Higher workshop throughput Lower R&M costs	Reduced need for specialised equipment		Reduced R&M cost for end customer	Faster service increases vehicle uptime
Easy access to parts frequently repaired or replaced	Enhanced mechanic ergonomics		Higher workshop throughput Lower R&M costs	Reduced need for specialised equipment		Reduced R&M cost for end customer	Faster service increases vehicle uptime
Clustering of parts frequently repaired or maintained simultaneously			Higher workshop throughput Lower R&M costs				Faster service increases vehicle uptime
Engine layout and parts are designed for intuitive R&M jobs		Reduced risk for human errors	No needlessly performed jobs or part replacements	Higher workshop utilisation			Reduced risk of customers experiencing service errors

Table 6.2 Connections between external stakeholder expectations and high-level objectives (continued).

External stakeholder expectation	*Ergonomic for Scania employees*	*Elimination errors during operation*	*Elimination unnecessary costs*	*High utilisation of investments*	*Short time-to-market*	*Competitive end customer offer*	*High end customer quality*
Good fit or product with current service procedures		Building on mechanic experience		Existing methods, tools and equipment can be used			Can increase quality of service jobs
R&M jobs can be performed with standard equipment and tools				No need for investments in specialised equipment or tools			
Predictable or dynamically updated maintenance intervals			No under- or overserving of engines			Predictability in service adds to offer	Increased quality perception
Predictable or dynamically updated part life length			Possibility for spare part pull system, hence less inventory				Reduced risk for vehicle failure
Engine design supports systems for quick and accurate diagnostics			Faster trouble-shooting No needless service jobs	Higher workshop throughput			Increased vehicle uptime

Note: Abbreviations used are in-process verification (IPV) equipment, product development (PD), production system (PS) and repair and maintenance (R&M).

6.2 Influential and Contextual Factors

During the study, a number of critical factors were identified to have an effect on the extent to which external stakeholder expectations are met and the predictability of the quality of the project output. As the factors were found to hold distinctive characteristics and to be influenceable to a various degree, two categories emerged which depend on how the factors are related to the studied process. When combined, the set of factors provides a basis of conditions and aspects to take into consideration in new product development projects, deemed applicable to a multitude of projects, ranging from those with a few number of functions involved to large cross-functional ones.

Some factors influence the project quality from "inside the box", meaning the approach to the factors can be selected by the stakeholders during the development process. If aware of them, these factors can be assessed and modified. The other group of factors instead affect the output from "outside the box", not being subject to modifications due to activities during the process, hence harder to change. They are project specific frameworks, pre-requisites, and lay the basis of the context in which its activities take place, hence affecting the impact of the other factors. The two types of factors were labelled as influential factors and contextual factors respectively, presented in Figure 6.2. The next two sections provide a presentation of the influential factors (IF1-IF7) as well as the contextual factors (CF1-CF8).

The list of factors is constructed from the comprehensive coverage of the NPD process, but with the set boundaries and only including the key stakeholders as specified in the scope. It is therefore neither to be considered as complete nor to provide a full representation of the picture.

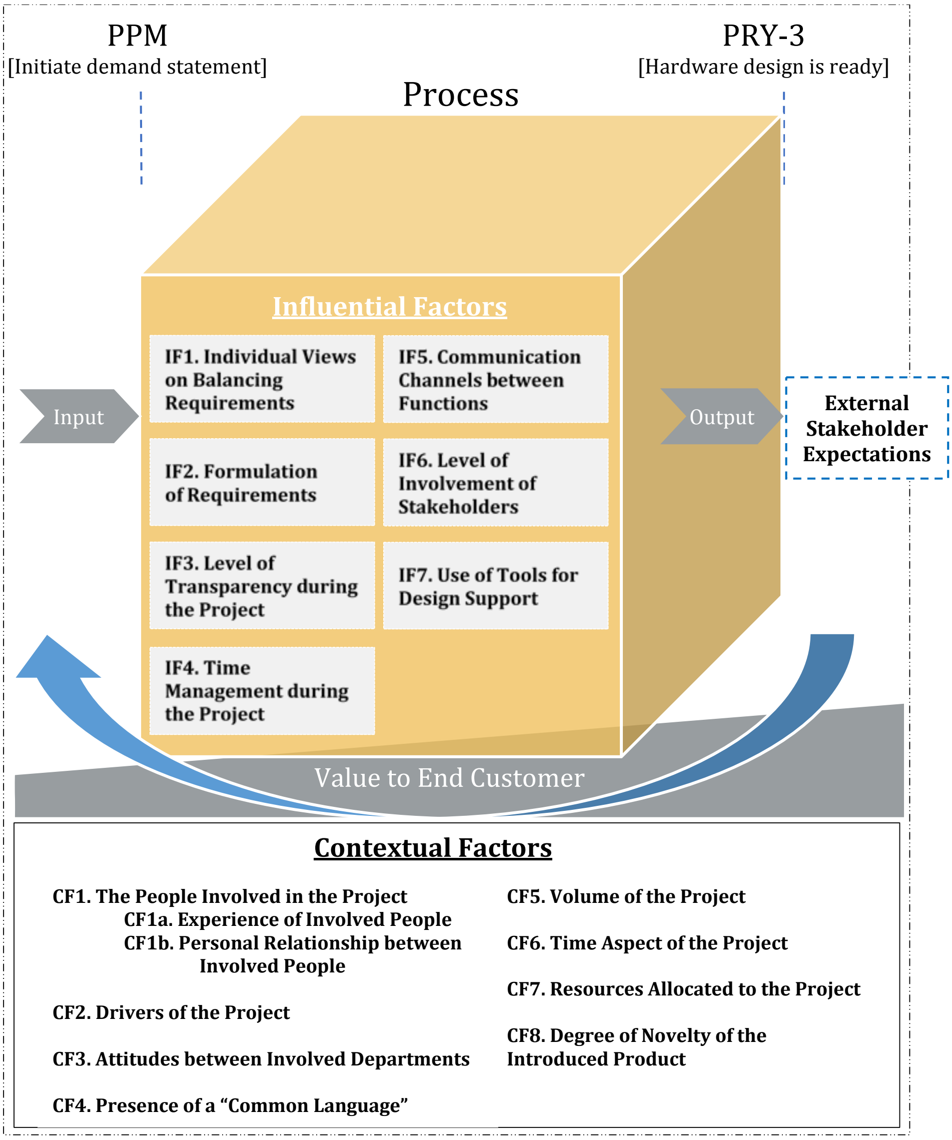

Figure 6.2 The NPD process in relation to the identified critical factors: influential factors affecting it from "inside the box" and the contextual factors having an impact from "outside the box". In order to fulfil the external stakeholders' expectations of the process output, these must be provided as input to the process, as illustrated by the blue arrow. Note that this figure is a simplified illustration, in reality the NPD process is much more complex and input is not only communicated in the start of, but also to a great extent throughout, the development process.

6.2.1 Influential Factors

IF1. Individual Views on Balancing Requirements

The view of how to balance the requirements communicated from several external stakeholders depends heavily on the design engineer receiving the information. The balancing activity is not performed by usage of a standardised method. Trade-offs and design decisions are rather supported by either experience, personal preferences or guidance by project drivers. Demands supported by financial implications or communicated in person are both seen as preferred in a balancing situation.

IF2. Formulation of Requirements

How requirements are presented when being transferred affect how they are translated into the design. Some requirements are deemed easier to make use of in the detailed design but preferences of on what level the requirements should be communicated vary, between design engineers as well as within the functions. Requirements in form of “static wishes” are hard to relate to and not considered to provide valuable information. The need to further specify the incoming requirements can be an indication of an insufficient quality of the transfer scope.

IF3. Level of Transparency during the Project

A higher level of transparency is a facilitator to the value creation during projects. Stakeholders providing input and investing time by actively taking part in the concept and product development processes want updates about in what stage the project is and what decisions are being made. They also need to take part of the product characteristics as it evolves in order for the process to benefit from their value-enabling capabilities. The transparency in the information flow also appears to affect the attitude the functions hold towards each other, as is presented in CF3.

IF4. Time Management during the Project

The view of time horizons vary between the functions, which complicates the transfer synchronisation. Several functions are dependent on the provision of information in order to pursue their work, so the input should better be transferred when it can be efficiently used by the receiver. The influence of time management increases later in the process as eventual delays accumulate during the project.

IF5. Communication Channels between Functions

The means used to communicate between the functions are diverse, with personal contact as the foundation of the transfer management. This makes for efficient information transfer but reduces the possibility for others to take part of what is said. However, the channels vary depending on when in the process the information is transferred, what information package is being transferred and who is the sender. The transfer management influences how information is translated into design or used in process procedures. This also shows the importance of which people are involved in the project, as is presented in CF1.

IF6. Level of Involvement of Stakeholders

An active involvement is regarded as positive and the requirements of participants being personally engaged in the projects are more likely to be acknowledged and incorporated in the design. Cross-functional meetings to assess the design is an increasingly common element in the projects but those invited do not always attend.

IF7. Use of Tools for Design Support

The extent to which the existing tools, providing guidance to the design process, are used vary between the functions. It also appears employees have created preferences about which ones are seen as valuable in their work tasks. The level of their perceived utility differ and so does the knowledge about their existence, depending on what department is assessed.

6.2.2 Contextual Factors

CF1. The People Involved in the Project

This factor is split into two parts, providing different perspectives in relation to CF1.

CF1a. Experience of Involved People

The experience of those involved in the new product development projects constitute a pre-requisite for how the project is carried out, thus affecting the output. This goes both for the design of products easy to assemble as for the management of requirements during the concept development.

CF1b. Personal Relationship between Involved People

The individual's personal network within the organisation is an important tool in the design process. How information is flowing heavily depends on the parties involved, e.g. how used one is to work with another and the character of the relation, influencing how the information transfer is conducted during the development process. It also affects the extent to which it is documented which can be critical if a participant leaves the project.

CF2. Drivers of the Project

A project can be initiated from a number of different drivers ranging from legal requirements to market opportunities. What initiated the project and who manages it affect for example which decisions are made in trade-off situations and which attitudes are found among the involved. It also directs the communication since some parties will perceive more incentives to be actively involved in the project.

CF3. Attitudes between Involved Departments

How the involvement of the function, especially early on, is perceived influences how the input is treated, requirements being met to a greater extent if appreciated.

When input is perceived as important (not as incongruous wishes) it enables for requirements to be translated to the design. Empathy towards assemblers positively affect the features of products introduced on assembly lines and attitudes towards design engineers influence the way to provide input and support during the process.

CF4. Presence of a "Common Language"

A common language among project participants facilitates understanding and reduces the risk of miscommunication. There are discrepancies in the views of what terms like "concept ready", "requirement list" and "requirement balancing" mean, potentially affecting the way they are approached by different functions.

CF5. Volume of the Project

The expected volume potential of the developed product affects the extent to which existing systems are likely to be adapted to fit the new product. For low-volume products, investments are more difficult to motivate and inefficient solutions to assembly and service accepted to a larger extent. High-volume project usually have higher status in terms of investments, cross-functional engagement and optimisation of related processes. Also, the extent, character and efficiency of communication vary depending on the volume of the project.

CF6. Time Aspect of the Project

The time allowed for development activities in relation to the extent of the workload affect the activities performed. When time constraints are strict, project participants may act differently, e.g. by leaving out design assessments or verification tests. Functions that are active late in the process are often more affected by time constraints as they have smaller margins before planned launch of the product.

CF7. Resources Allocated to the Project

Resources allocated to the project in terms of number of participants (man hours) and financing differ. The availability of employees at each function influences the importance of synchronisation with other projects running in parallel, the need to prioritise and the possibility for the function to participate actively.

CF8. Degree of Novelty of the Introduced Product

The novelty of an introduced project, determined by the extent to which existing product platforms, technologies, systems and experience can be used during the development project, affect the introduction and possibly also the project output. Novel products are more complex to develop and introduce, the extensive amount of changes from current products induce risk of deviations or mistakenly omitted aspects. An awareness of the high degree of difficulty may however result in a higher quality of the output than do projects with a lower degree of novelty.

7 Analysis and Discussion

This chapter starts with a discussion of the methodology used in the study. Next follow reflections on the identified external stakeholder expectations and their experiences as value enablers during the NPD process. Thereafter is an analysis of the factors that can hinder or enable the value creation in the development projects, thus affect the level to which the expectations are being met. Lastly, findings related to a learning environment are discussed, so as to provide an understanding of the current situation and the possibilities to apply the results in the purpose of increasing the integration of external stakeholders in the NPD process.

7.1 Evaluation of Methodology

The research design was created during the first part of the study, developed in parallel with the identification of the chosen scope. Allowing for the design to be flexible, so that adjustments on e.g. the data corroboration stage could be made as the study evolved, enabled an explorative study. Using a variety of qualitative methods also supported the explorative character of the study and reduced the risk of not covering all aspects of stakeholders' interests. The relative advantages of each method were likely successfully exploited, since studying methods on beforehand laid ground for thorough preparations and avoidance of potential pitfalls. The approach as a whole was however person-dependent which was clear for example as the interviewees had to devote their time and could also chose which information to share. Even though preparations were made both regarding the material and practical matters, such as sending out invitations on beforehand, set-backs occurred due to this person-dependency. An example is in one of the focus groups, where the invited development line assemblers did not show up resulting in their perspective never being captured.

All interviewees during both the pre-study and the raw data collection proved knowledgeable and eager to help; both with providing information, indicating interesting areas for more thorough examination more thoroughly and in the identification of other key people. The pre-study however blended into the raw data collection as valuable information about the studied process was uncovered already during the pre-study and as grasping the picture of the NPD process via interviews and documents took longer than estimated. An improvement could therefore be to keep a stronger focus on understanding the development process in the initial phase, using a few key sources, instead of receiving new learnings about the NPD process continuously while the data collection was pursued in parallel. This would have provided the authors with the possibility of moving on to a more directed information collection stage related to the research questions. The difficulty with this alternative approach lies in locating key sources with extensive, cross-functional and objective knowledge about the process.

The careful documentation of all data collection activities reduced the risk of information being lost in the process but an improvement of the method could be to transcribe all the interview material. However, this would require much time and the activity was considered not to provide enough value to be justified. Another improving action could have been to include a handful of structured questions in the interview guides instead of only semi-structured. Doing this, gaps in the data could have been avoided and comparison of answers from different functions facilitated.

The coding stage was given large priority in the study since this step was considered essential in going from a large amount of categorized data to a structured presentation of the collected and extracted information, from which working hypotheses could be created and further analysed. The coding was an iterative process conducted by repeatedly grouping information in different ways. Different categories were created and dismissed until the final ones emerged, which was a time-consuming activity but it essential to break down and sort the data in categories well suited for the study.

When collecting the data, it became clear that the amount available is extensive. Hence, a great challenge was to decide when saturation could be deemed as achieved. Within a few weeks some areas of the study appeared to be saturated, especially those concerning priorities and general working processes. In other areas, such as the details of the working process and attitudes between functions, new and sometimes puzzling information emerged up until the end of the data collection period, indicating either saturation was not achieved or that interviewees had different ways to express themselves leading to misinterpretation of the data to be compared. The interviewees were though all seen as providing perspectives adding value to the study, since care was taken to include employees from different levels in the organisation and individuals providing different views of the process studied.

The authors took great care in verifying the collected material, making sure nothing was misinterpreted. Thus the results should be credible and applicable. Interesting is however to reflect upon whether the result would have been the same if the choice had fell upon other interviewee objects, which is most likely true to some extent. Basing the selection on recommendations might have steered the perspective only to those very engaged in the process or particularly forthcoming. Still, interviewees and focus group participants were perceived by the authors to have different personalities and views of the process, hopefully minimising the effect of this potential error source. Much time was also devoted to verify the final results, to mitigate the risks of misunderstandings being part of the findings. The high-level objectives, expectations and critical factors were all triangulated by basing them on information from several sources and they were also evaluated by third parties; the internal supervisors as well as a project manager within DE and a development engineer for service methods. This provided new angles and a possibility to perform small modifications so that results are likely to be regarded as valuable to the company.

The research design can most likely be applied when performing studies at other companies. It provides a well-structured approach, covering many methods which increase the variety of the information collected and reduce the risk of bias. But, this design requires discipline and a high quality of the written documentation: meeting minutes, notes taken during participant observations etcetera. It also depends somewhat on the employees; where lays their interest, are they eager to provide help and is there sufficient time for that? Also, keeping the large amount of data in mind, a narrower scope decided upon earlier in the study would have facilitated to keep focus on the research questions when pursuing the study. The process must also be transparent for others to understand; hence an extensive amount of supporting text is needed to substantiate the work. A negative aspect is also that the selected method was rather time consuming, as information was collected via personal meetings with both authors being present. However, if these aspects are considered and managed, the variety of methods provide for a comprehensive information bank which covers many aspects, is interesting to work with and reliable to draw conclusions from.

7.1.1 Reliability of Surveys

Measures were taken in order to minimise bias, potential misinterpretations and a low response rate of the surveys. Still, discussions regarding sampling errors and sample bias is applicable. For the survey to design engineers, it was regarded as out of the authors' control since the possibilities to choose the sample from the sampling frame was greatly restricted by organisational influences. The authors also aimed for design engineers whom had any (short or long) experience of working with product development, i.e. not only follow-up projects and preferably with experience from the early phases of PD and CD, something which could not be ensured simply by looking up the provided names at the intranet. One respondent explicitly stated as having no experience of working in the early stages of the NPD process, which of course can have influenced the answers provided. Additionally, one should be aware of that a larger sample would have been preferable to reduce the risk of producing results uncharacteristic of the investigated population and that sample bias could have been further reduced by maximising the coverage of the population. The response rate was almost 60 %, which is high for this type of survey hence deemed as satisfactory.

The survey to line assemblers was too subject to potential sample bias since a social gate-keeper was used to reach the respondents. This was done to act professionally (not show up unannounced handing out surveys) but also to ensure time was allowed to provide some assemblers to respond to the questionnaire. The distribution was hence only made to three out of 13 assembly areas in total, all located on the same line and two areas located rather early on the line, where the engine is not yet very differentiated. This makes for a potentially homogenous sample not reflecting the whole population.

7.2 External Stakeholder Experiences and Expectations

7.2.1 Existing Methods Supporting Cross-Functionality

The involvement of external stakeholders in the NPD process was overall seen as strong although some improvement opportunities were found during the study. Several methods to support cross-functionality are already implemented in the development process, noticed for the engine assembly function as well as vehicle service information, and there appears to be a correlation between direct communication with other functions and active participation in the process. Used methods building on direct communication to support cross-functionality are layout meetings and Virtual Builds but also the deviation report system FRAS, where functions can report deviations directly between each other. The strong reliance on verbal communication and meetings can reduce some barriers, such as organisational or cultural ones, as each function's goals are being assessed in relation to those of others. Through dialogues, the group of participants can more or less spontaneously make mutual adjustments to their actions, providing for a behavioural change guiding the upcoming stages in the development process. So, as also explicitly stated by an interviewee, these occasions aid the development of a deeper shared understanding and the creation of coordinated views, thus helping the feed forward learning process (from interpreting to integrating). However, in order to succeed all involved parties must be present, which is not always true today, not even at Scania Södertälje where the collocation of functions provide good conditions for cross-functional meetings. It should also be stressed that a culture relying on meetings for communication can also create barriers, e.g. between the site in Södertälje and other production sites in Sweden. In addition, the working method makes it difficult to get an overview of wishes and requirements present in a project, since they enter continuously and through many different channels.

Theory advocates written communication as a way to enable integration and improve the communication, as it is a more formalised and comprehensible way of transferring the information between sender and receiver. It also pinpoints the importance of documenting the process since what has been communicated verbally is not accessible by others. Verbal communication is however a faster way to communicate between employees and additionally considered as essential for the NPD process at Scania. Thus, the written documentation should increase without necessarily doing so on behalf of the verbal communication. In order for this to be efficient, the information must be presented in an easily accessible language, which shows the importance of developing a common language between the functions.

7.2.2 Reflections on Identified External Stakeholder Expectations

Identified external stakeholder expectations differ in how well they are considered today and in assignment of responsibility. For e.g. ensuring easy positioning, insertion and fastening of parts, the responsibility lies on one or a few people reducing the risk of the aspect being forgotten. Others, such as alignment between the product and the production system, are dependent on the involvement of multiple stakeholders. Interviewees expressed that the path towards alignment is not always agreed upon on beforehand but the solution can be rushed in order to meet critical deadlines. These type of expectations also risk not to be sufficiently considered and if no one is clearly assigned responsibility for expectation fulfilment, the feedback of unfilled requirements will likely suffer as well.

Upon formulation of the external stakeholder expectations, it was noticed that the same views were often presented from both sides of the studied interfaces design-assembly and design-R&M. This points towards a widespread understanding of the goals or difficulties of other functions, if not on a detailed level so at least in general, which can be a result of the culture of cross-functional collaboration. Still, the assembly and the R&M functions were repeatedly mentioned as having contradicting requirements, not being compatible in their goals or simply being each other's opposite in the process. The functions do, naturally, have different requirements regarding some aspects but did also express similar preferences of others, such as minimisation of part variants over the product range. While it can be a challenge to completely satisfy both functions, there is a probability for the difficulty to be exaggerated.

To put the results in a broader context, the identified external stakeholder expectations were compared to theory on design for assembly and design for service principles, the most similar fields in research. When assemblability is described in literature, focus is typically on detailed characteristics of a product why a working hypothesis of the study long was that the solution lied in a detailed definition of these terms. It was however found that the external stakeholder expectations regarding engine assembly spanned a much larger range and included working processes, production systems and workshop equipment as well as the product itself. Focus was rather on alignment and synchronisation than on isolated matters, making existing DFA guidelines such as the Boothroyd-Dewhurst Methodology incomplete as evaluation criteria. For DFS, the most suitable available theoretical model is the

AR^{3}T^3 methodology, as time and access were found to be the most important aspects at Scania. However, the guidelines of the methodology is not fully consistent with the collected material on external stakeholder expectations regarding engine R&M, where diagnostics and prognostication were strongly emphasised, not only active service time. Thus, in order to be useful, the evaluation criteria still need adaptation to Scania priorities.

7.2.3 Comprehensiveness and Reliability of Identified Expectations

The selection of informants was deemed to largely impact the reliability of the results wherefore triangulation of data was employed and saturation in the interview process sought. With all external stakeholder expectations tracing back to at least two informants, often more, and as a variety of data collection methods were used, they are all considered as triangulated. Comprehensiveness is somewhat more difficult to ensure. While efforts were made to include as many informants as possible in the data collection and new information eventually began to revolve around already discussed topics, there is no guarantee of a comprehensive list. However, the authors believe most critical expectations are covered as employees on many levels and on both sides of studied interfaces were targeted. One potential gap in the results could be expectations considered obvious or implied by the informants, but not perceived by the authors. The comprehensiveness of the results could potentially be increased by also including executed data, collected by e.g. following a development project in real-time observing which expectations are communicated and discussing the status of the product as it evolves.

7.3 Influential and Contextual Factors Affecting Projects

7.3.1 The Problematics of Fulfilling External Stakeholder Expectations

The identified external stakeholder expectations are not unexpected results in themselves but rather understandable. Remarkable was instead the fact that they are not always met or even always considered feasible to meet, as obvious as they may seem. It is clear that the external stakeholders are aware of the importance of active participation in the new product development projects and that they take responsibility for ensuring their own interests are taken into account. Their contribution to the projects is also appreciated by the R&D function where they are perceived as knowledgeable in their respective areas and can provide good support during the projects. Still, external stakeholders do not always feel involved in the projects, either because they do not have the resources or because smaller teams are preferred over cross-functional participation, most commonly occurring during concept development. Failure to fulfil stakeholder expectations might derive from how their requirements are formulated and communicated, where they might be misinterpreted, that expectations are deemed as having low priority or for other reasons become disregarded. For the engine assembly function, as a stakeholder being active late in the projects, one inhibitor to integration could also be the traditional view of them as a receiver of proposals. The function can furthermore be seen as the ultimately responsible for ensuring alignment between the product and the production system, rather than one part in a two-way collaboration. Findings thus indicate that external stakeholders are already seen as value enablers of the product development process by many, at least to some extent, but are not always given the opportunity to act accordingly.

Hinders to external stakeholder value creation appears to escalate in pressed situations, e.g. when time restrictions are tough. When time is scarce, one solution today seems to be reduction of the front-loading of the process so that fewer functions are involved early on, everyone focusing on their absolute core responsibilities. This clearly goes against lean product development recommendations and is not advocated by any of the information sources. Still several stated that it happens, suggesting that while the company is successful in implementing lean methods in a normal situation, they are not always the intuitive options when under pressure. This could provide an explanation to why expectations are not always met and why external stakeholders sometimes feel excluded from the development activities.

If the delivery at the process boundaries do not meet the expectations and the transparency has been low, it can undermine the process as the stakeholders perceive their input as not being of value to the process or not to be taken into consideration. Hence, in order not to counteract their participation in the value creation and to create an acceptance for the output, stakeholders should be allowed to be involved throughout the process.

7.3.2 Reflections on Identified Factors

To capture the phenomena found to affect the extent to which the external stakeholder expectations were met, the factors were formulated and presented in parallel with the visualisation of the studied process. The identified factors can both serve as facilitators and obstacles in creating value throughout the process. For example, the experience of those involved in the new product development projects constitute a pre-requisite for how the project is carried out, thus affecting the output. Experience can speed up activities and contribute to a pro-active approach where potential assemble complications are considered early in the projects. On the other hand, it can result in that available tools providing guidance for the design and which may be a basis for creation of a common vision, are not consulted by the employee.

It was found that similar categories of factors were identified to be present in the new product development process at Scania as in the study conducted by Lakemond et al. (2007). The great majority of their factors, presented in the literature study, were related to information transfer management; where the transfer synchronisation, transfer management and transfer scope were connected to five out of six factors seen as critical in bridging the interface between the product development and production. Thus, the critical factors all relate to subjects lifted in this thesis, e.g. continuous communication and an active involvement, which are covered by the influential factors of this study. Also, managing the information is an element in many of the proposed factors in this report, indicating this is an important issue during product development. On the other hand, the contextual factors presented in the study by Lakemond et al. (2007) are not at all as strongly related to the findings of this study.

Since activities and value creation is less tangible in a LPD process than in the analogous lean production, improvements are not achieved merely by implementing changes in the physical activities. The factors reflect that the flows consist of information and knowledge, thus efforts should be made to reach an improved collaboration and to raise the level of transparency in order to meet stakeholder expectations. To increase a shared understanding, the development of a language is also necessary. That functions have developed their own parlance is not rare or surprising per se but rather a natural phenomenon in large organisations, where it can fill the purpose of creating a more efficient intra-functional communication and enhancing the feeling of an internal cooperation. But, the verbal nuances should be dealt with efficiently in cross-functional processes or else there is a risk of a reduced quality of the transfer scope. Misunderstandings was found to be commonly experienced in projects, showing that what is believed to be obvious by the sender is not necessarily interpreted the same way by the receiver of the information. Thus, in order to reduce this element of uncertainty it should be discussed what is a requirement list, what is included in the definition of assemblability and so on. This would lay ground for the creation of a common language between the functions, believed to positively affect the bridging of interfaces.

The awareness of design engineers being under high pressure, taking into account requirements from several functions, is important to share, and the attitude should be to encourage the provision of high-quality information as support throughout the design process. It is seen as positive that design engineers expressed an understanding of the value to early receive input and merge perspectives from key stakeholders into the design in order not to miss out on critical aspects. If one perspective is perceived as dominant, as was the case of DE from the view of YS, this can counteract the achieved integration, thus lowering the chance of an effective and timely transfer (e.g. level of detail match the level required when input is to be used in the design). If the integration is badly managed, the perceived use of the information transferred can also become biased, interpreted as being of low utility. This implies a risk in the process, since all functions can provide their unique knowledge to the development. By aiming for a deepened shared understanding of the project specific frameworks, the development during the project can be perceived less differently by the functions. This would help reducing barriers resulting in an increased probability of organisational learning taking place, which would underpin the process efficiency. In new product development where many functions are involved there is of course a variance in interpretations of, and attitudes towards, the way of working (negative or positive to performed activities, about other functions, about the quality of the information transfer etcetera). The awareness of the factors can therefore serve to illuminate possible implications, which should be dealt with by proper managerial means. The influential factors can be modified during the projects, if situations arise where needed, whereas the contextual ones are harder to assess while the project is running, but should rather be thought through before the initiation.

7.3.3 Comprehensiveness and Reliability of Identified Factors

The factors, presented as the two different types influential and contextual, are factors deemed as critical in that sense that they affect the output of the projects. They have been drawn by the authors, based on the collected and processed data. Hence, the factors are constructed on the basis of activities, identified problematic interfaces or phenomena, either implicitly indicated or mentioned, by one or several key stakeholders. Some factors, for example the experience, was directly expressed as having an impact on how well a new development project meet or had met the expectations. The provided list is not offering a full coverage and can most probably be made longer if that brings marginal utility. It cannot be pinpointed whether or not these are the *main* critical factors affecting the extent to which external stakeholder expectations are met during new product development, as was the formulation of the research question. What can be ensured though is they all can provide implications, hence negatively affect the output, or facilitate the value creation and use of value-enabling capabilities during the NPD process, resulting in a higher quality of the project output.

The selection of informants may have affected the reliability of the results in the study, wherefore triangulation of data was an important element. An approach that could have been used to further mitigate bias is performing a case study, where a few projects are assessed as they progress, to open up for factors being confirmed or disregarded. This would combine retrospective and real-time cases but would require a longer time-span, since new product development process is complex and time-consuming. If performed, it can bring insights about the longitudinal relevancy of the critical factors – since there is a possibility the factors presented can change from time to time as the company work with their processes. It can also change since individuals are adaptive and changes occur in attitudes and perceptions. This is probably the case here, where experiences strongly influence the interviewees' references, meaning that the view of for example other functions can change quickly. This even happened during the time of this study, where an interviewed project manager expressed that the vehicle service information function often communicates requirements on a general level. The same project manager later reported that in the currently running project, their involvement is instead much more active and that they support the process with requirements also on a detailed level. However, the opinions, views and attitudes were often reflected from several informants, probably capturing the more holistic picture.

7.4 Towards an Increased Stakeholder Integration

It is not always obvious who should be responsible for fulfilling the identified external stakeholder expectations as benefits can be shared by many and solutions can come from several directions. LPD theory advocates the use of chief engineers with full vehicle responsibility in such situations, as a responsibility shared by many easily becomes a responsibility of no one. Employing a similar system, either using the chief engineers or assigning the duty to other technical project managers could be a step towards ensuring efficient fulfilment of the external stakeholder expectations, even in more complex cases when a large amount of functions are involved. Another facilitating working method would be a stronger front-loading of the process – increasing the early involvement of external stakeholders by moving further towards SBCE and present sets of conceptual solutions to a large group of external stakeholders holding multiple roles within their functions. Scania already appears to employ set-based working methods to some extent but, as many interviewees expressed themselves, functions are rather receivers of one evolving solution than given the opportunity to review several parallel alternatives. Hence, an extension of this working method is advisable. If expressed early in the projects, many of the identified expectations are deemed able to meet in several alternative ways. By communicating the expectation and the desired value in a cross-functional setting, a cross-functional solution space can also open up. For example, easy access to parts frequently maintained is not solely a question for those designing engine layout but also for service methods developers and so solutions can come from both ways.

Employment of “Design for X” tools, in this case DFA and DFS, is a means to integrate the requirements of stakeholders rather than the stakeholders themselves. As the level of detail of the criteria in such methodologies differs from that of external stakeholder expectations and as creating an understanding of each other’s work was deemed more important than only receiving input from other functions, these tools are not the focal point for improvement suggestions in this study. However, they must not be disregarded as methods as they can complement given recommendations.

Regarding the factors, they are merely representations of process phenomena and do not bring value in themselves. Still, an awareness of them at managerial level in projects (e.g. object leaders) may be the first step towards process improvement as they provide a perspicuous explanation for why a certain quality of projects is reached. Before being fully applicable, the identification of the factors must be completed with the creation of a method for how to benefit from them and put them to use in projects to maximise value creation. This is outside the scope of the thesis and will not be discussed in detail, but two examples on how to turn awareness of the factors into value creation are presented below.

Example of how to consider factor IF3: If the engine assembly function (DE) is to deliver requirements early on in the NPD process, i.e. in the CD process, but is not desired as an active participant during this stage, the information on the status of the design process must flow to DE in order to facilitate for the function to act as a value enabler. So, the involved functions can for example modify the level of transparency by making sure to share this information if available. However, a challenge is to not use an extensive amount, but rather the desired well-defined deliveries. Another way of dealing with this factor is to frequently use the tools providing the external stakeholders with up-to-date designs, allowing the functions to quickly perform digital test assemblies/digital test disassembles and hence strengthen the possibility of a high level of quality of the project output.

Example of how to consider factor IF7: If it is noticed that functions are not being active in the process to a desirable extent, ideally they are addressed with questions regarding their expertise in design issues or provided by feedback so that their knowledge is still captured and an increased participation is encouraged.

7.4.1 The Presence of a Knowledge-Based Culture

A company culture building on knowledge sharing and organisational learning is believed an important facilitator for integration of external stakeholders, as their competence is then captured and spread throughout the organisation rather than being local or circumstantial. While studying the NPD process at Scania, it was found that many existing routines and structures are in line with what researchers in the field has identified as facilitators of OL. The Lesson Learned reports are examples of post-project audits to learn from what has been regarded both as positive (and thus should be included in the working methods), and what deviations or obstacles have been encountered (and should be eliminated in future projects). Review sessions, such as layout meetings and VBs, are in place where the design is cross-functionally assessed and its current and potential future flaws discussed. Best practice case studies are also part of the way of working at Scania Södertälje, where the Knowledge bank provides an example of how learnings shared by the employees are disseminated in the organisation. What is also evident is the presence of a learning culture permeating the organisation, which was observed in everything from governing documents to working methods.

During the study it became evident that there are information and methods available which could provide support in the cross-functional value creation but which are not always consulted or even widely known within the organisation. It was also seen that employees have created preferences about which ones are considered as valuable in their work tasks or even developed their own versions and adaptions when putting the formalised structures into practice, e.g. assemblers not following the standards or design engineers not consulting checklists. Thus, part of the work seems to be done in a more individual manner, guided by intrinsic knowledge. The Scania philosophy highlights the importance of continuous improvement through exploiting the knowledge of the individuals. Still, the experience of individuals and their specific ways of working was seen as hard to translate into standard working methods available to the rest of the organisation to benefit from. As an example, it was said that for some design engineers it is sufficient to just throw a glance at a drawing in order to consider it to be dysfunctional while others had to consult test results. It appears that highly subjective expertise is present within many functions, but that few feed forward processes are in place to explore this. By going from intuition towards institutionalising as illustrated in Figure 4.3, the full value of individual expertise can be captured by sharing it with others and potentially even including it in the company's general knowledge base.

An understanding of what is possibly gained by collaboration is an important step towards integration, where the company should make sure to assess how value was created in projects perceived as well-functioning by several stakeholders and which were the enablers for this to happen. During the study, the same project was spontaneously brought up in both focus groups, as example of an efficient cross-functional development process. When this occurs, that projects where several key stakeholders are content with the extent to which their expectations have been met, it is recommended to make sure examinations are performed and projects are well documented, so that yielded learnings can benefit future situations. This should be done during the project so that information is not lost before the Lesson Learned is drawn at the end of the project, since at this point it can be hard to pinpoint what went well and trace back what were the enablers. Also, the reports must be easily accessed in later projects, mitigating the risk of learnings being unused and forgot due to the large amount of accumulated project information at the company.

Based on the above, it seems Scania is currently in a situation where the institutionalising is prevailing the feed forward processes to take place as much as would have been beneficial. In order to enhance the learning, bottlenecks that constrain the learning flow, such as tacit knowledge not being addressed from individual to group level, should be receiving attention. This would allow for an even stronger knowledge-based culture and an enhanced possibility of using stakeholders' value-enabling capabilities. If the company manages to better balance the exploration, i.e. the feed forward process, and the exploitation, i.e. the feedback process, Scania can gain responsiveness in their NPD process while still utilising the knowledge and learning from its employees.

7.5 Generalisation of the Results

A better understanding and an enhanced appreciation of the external stakeholders in the concept and product development processes are believed to increase the quality of the NPD process output. As the study was concentrated to the NPD process at Scania, the details of the results and consequently their applications are company-specific. Comparing the findings to similar studies and drawing parallels to theory however indicates an alignment with existing knowledge in the field, suggesting a possibility for generalisation of the results.

A first step in extending the results could be inclusion of more stakeholders related to engine assembly or applying the methodology to the development of transmission, chassis, cab and body at Scania. As the CD and PD processes, the pre-requisites for development activities and the working methods are similar for these functions (although not exactly the same), similar patterns in stakeholder expectations and critical factors can be expected to be found. The formulation of the high-level objectives make them applicable for other stakeholders as well, which was a set goal, as none of them specifically targets engine assembly or engine R&M but rather Scania's core processes and customers. Tendencies identified in the Scania setting, such as the effect of attitudes between functions and chosen means of communication in projects, can likely also be found in other companies.

While the sets of influential and contextual factors should not be directly applied to other settings they can be used to create an awareness of the types of factors that can potentially affect the output of development projects in other companies. Apart from spreading an understanding of the value of having identified such factors, they can be used as inspiration for conducting similar studies and facilitate such initiatives. The same goes for the external stakeholder expectations where a structured representation of the set, together with the benefit they each create, can provide a basis for increased understanding of the underlying needs of the stakeholders and facilitate integration of their requirements.

8 Concluding Remarks

In this final chapter, the conclusions of the study are presented with a focus on those relating to the research questions. The contribution of the thesis is discussed, where the authors see a potential applicability of the methodology and the results both at Scania and at other companies. Suggestions for further research areas are also provided.

8.1 Conclusion

Both research questions were answered through the study, if not fully so at least in large part. The first research question of the thesis revolved around external stakeholder expectations, more specifically those regarding engine assembly and engine R&M. During the study, 22 such expectations were derived from collected information covering all from ergonomic work environment and part access to standardisation within the engine or the entire range of engines. To emphasise the value of the expectations, increasing the possibility of them being met in the NPD projects, they were all linked to one or more of seven high-level company objectives developed specifically for this study. When un-surfacing the underlying expectations of the requirements regarding engine assembly and engine R&M, the impression was that these are not always as contradicting as often declared. Thus, the functions should consider taking a common approach more often, benefiting from each other's negotiating power – one being very powerful internally with their in-house production system and the other a key player for a profitable aftermarket. Their value-enabling capabilities both lies in supporting the design function during the NPD process, to avoid unnecessary iterations, and in securing products are well suited to the sub-sequent processes of assembly and R&M which will affect the company long after the NPD project is terminated.

Although the expectations might appear natural to fulfil, they are not always met during projects. Hence, the external stakeholders' capabilities as value enablers in the projects are sometimes impeded. Reasons for this were found to for example relate to either lack of resources, excluding attitudes towards the functions of engine assembly and vehicle service information in some situations or how requirements connected to the expectations are formulated and communicated. While several tools were considered as potential facilitators to include the external stakeholder perspective in the design, reducing the reliance on subjective evaluation, none of the theoretical methodologies were found to provide sufficient assessment in itself. Instead, the nature of the information flow between company functions was deemed as the most critical aspect to ensure fulfilment of requirements, wishes and expectations of external stakeholders. For revolutionary proposals with a high degree of innovation, which would require large differences from the current state, creating a common vision of the future state within the organisation is important. In doing so, risk can be minimised by taking small steps towards the vision during a sequence of projects.

A more thorough examination of factors affecting the extent to which external stakeholder expectations are met, connected to the second research question, resulted in that two distinctive categories emerged; influential factors which influence the output from within the project and contextual factors which make up the fundamental conditions for the project influencing the output from the outside. This categorisation is consistent with findings of previous research in the field, indicating feasibility. Several identified factors concern the management of information, e.g. how, when and what information is being transferred, and the importance of transparency in the information transfer should be stressed in particular. Transparency was found to enable stakeholders staying updated on the progress of the project even when not personally involved. It also increases the understanding of the project output and is by extension hypothesised to increase the acceptance of the developed product and why one's requirements could not always be met, while a lack of transparency could be counteractive to cross-functional integration as stakeholders perceive their input as ignored. The intended use of the factors is to bring additional awareness to the projects regarding the context in which it is carried out and how value creation can be stimulated in the project using the influential factors, a step towards increasing the quality of the project output. More detailed recommendations are not developed in this study but are subject to further research.

Implementing new routines for the working process during concept or product development, or improving current ones, require a company culture where new learnings are embraced and diffused within the organisation. Therefore, the studied process was evaluated in how well it supports organisational learning and contributes to a knowledge-based culture. It was found that there is a range of methods supporting OL, such as Lessons Learned and a Knowledge bank. However, these are not rooted among all individuals who should make use of the methods. The same conclusion was drawn about the tools aiming to increase knowledge build-up within specific areas, e.g. a DFA checklist. Individually adapted working methods were sometimes seen to be preferred over institutionalised methods. A strong preference for knowledge-sharing through personal communication was also apparent, which should be taken into consideration when developing the work routines. For example, active involvement of external stakeholders in the development processes does not have to require personal participation, but if most information transfer takes place on meetings and perspicuous documentation is scarce, stakeholders are somewhat excluded if not able to attend.

A widespread appreciation of the value each stakeholder, external or not, can bring to the project is deemed important to increase their opportunities to create value during the process, as decisions were seen to rely heavily on personal judgement and attitude of participants. It is thus important to pinpoint the contribution the stakeholder brings and from both sides of functional interfaces make the effort to transfer knowledge and share information. By this, the collective expertise of Scania can be efficiently exploited in the concept and product development activities allowing for a more efficient process of bringing new products to the market.

8.2 Contribution

The main contribution of this thesis from the viewpoint of Scania is an increased awareness of how the concept and product development processes are perceived by involved functions, focusing on five key stakeholders. Basing the study on the perceptions of representatives from various functions gives an overview of the performance of the cross-functional collaboration during the projects which cannot be reached by taking a more functional approach. The broad perspective opens up for explanatory conclusions on the current state of the new product development process and its functional interfaces, which can hopefully serve as inspiration for improvement initiatives to further increase its performance. Presenting a perspicuous overview of expectations from several stakeholders, some overlapping the interfaces, is also believed a novel and useful approach as goals or aspirations are often formulated and presented separately for each function. Also, the clear connection to the value created if expectations are fulfilled is believed to be useful.

Some of the findings of this thesis will be used as information source in the research conducted by the internal supervisors, meaning the study contributes to further building of theory within the field, in addition to its industrial contribution. This primarily applies to the external stakeholder expectations identified in the study.

8.3 Limitations and Recommended Further Work

The final results provided in this study are deemed to be of relevance for the company, but are also somewhat limited in their applicability and should be seen as a basis to build on. The external stakeholder expectations presented are developed with the function of engine assembly and vehicle service information being the stakeholders handling the output at the process boundary, hence the resulting expectations can only be applicable in the purpose of taking their perspective during the process. Another limitation is that the factors identified are not verified to be perceived as present when taking other stakeholders’ perspective. Hence it cannot be ensured that the same factors are experienced by them and so this study does not yield a cross-functional view of their presence in development projects.

A first recommendation would therefore be to expand the study to include other key stakeholders and choices of value enablers, so as to increase the generality of the list of external stakeholder expectations. By simultaneously exploring which influential and contextual factors are present, the understanding and awareness of what affects the quality of the project output can be deepened. By extension this can provide valuable means to address the factors and modify the approach to them to enhance the value creation in the projects.

In order to evaluate the quality of the projects, it would be useful to develop a method for the purpose of measuring the extent to which the stakeholders' expectations have been met. This surveying instrument can then be applied on projects to increase the understanding of how the factors affect the project output, e.g. if certain constellations are apparent, and also how to best exploit this newly incorporated knowledge.

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Appendix A Survey to Design Engineers

The survey to design engineers was created from information collected during the raw data collection and pre-study, as described in the report. It was distributed to 32 respondents from nine different design departments within the NM, engine development, at Scania Södertälje. The response rate was 59.4 %. First, the questionnaire is presented, followed by a presentation of how the data was coded and turned into the statements and questions. Lastly, all results are presented to substantiate the results presented under the corresponding themes in Section 5.2. The distribution of the close-ended questions are as circle charts to give the reader an easy overview, the yes/no questions as a diagram providing a perspicuous result, and finally the free text answers are all presented in table form.

A.1 The Questionnaire “The View of a Design Engineer”

Below is a translated version of the survey, presented in text form, as it was sent out as an Internet survey via Google Forms. The questionnaire was originally written and distributed in Swedish.

How many years of experience do you have working as a design engineer at Scania Södertälje?

Do you have work experience from the engine assembly at Scania Södertälje? If yes, please specify below how long (please enter your answer in years). If no, please fill in a zero (0).

Do you have work experience from the engine repair and maintenance at Scania Södertälje? If yes, please specify below how long (please enter your answer in years). If no, please fill in a zero (0).

Part with close-ended questions (statements)

You will now be presented to a number of statements linked to your role as a design engineer.

Please use your own experiences and perceptions when selecting one of the following possible answers:

"Agree", *"Somewhat agree"*, *"Somewhat disagree"* or *"Disagree"*.

If you feel that you cannot answer, choose the option *"Do not know"*.

Remember: you answer based on your own experiences and your responses will be anonymous, so please be as honest as possible!

The following statements assess the process of balancing requirements:

- I am expected to take a major cross-functional responsibility for meeting the received requirements
- Ergonomics is the factor with the greatest impact during the design process

If your response was "Somewhat disagree" or "Disagree", please specify which, in your opinion, is the most important factor in a decision situation:

(room for free-text answer)

- When balancing demands, I prefer supporting my decisions with requirements that can demonstrate positive financial results
- When balancing demands, I prefer supporting my decisions with requirements communicated to me via personal contact
- There exists a standardised method to balance between contradictory demands

If your response was "Somewhat disagree" or "Disagree", please specify what method you use:

(room for free-text answer)

The following statements discuss the process of communicating requirements:

- Requirements from DE are mainly communicated through personal contact
- Requirements from YS are mainly communicated through personal contact

If your response in any of the above was "Somewhat disagree" or "Disagree", please specify how requirements are communicated:

(room for free-text answer)

- Requirements communicated from DE have a high level of influence on the design
- Requirements communicated from YS have a high level of influence on the design
- If YS is represented during cross-functional layout meetings, their requirements will be met to a higher extent
- The production targets communicated by DE are hard to make use of in detailed designs
- The product targets communicated by YS are hard to make use of in detailed designs
- Communicated requirements often need to be further specified with the initiating part
- The project definition (PDf)/object definition (ODF) is used in the design process
- I find non-project specific "requirement lists" (e.g. DFA and SES) to be valuable tools in my design process

If your response was "Somewhat agree" or "Agree" on the above, please specify below which documents you are using and your opinion about them:

(room for free-text answer)

- Routines exist to provide feedback to the initiating demand provider of the requirements that cannot be met in the design

The following statements discuss the communication:

- The input received from DE in the yellow arrow facilitates the design process
- I experience a well-functioning support from DE throughout the design process
- Lesson Learned is an efficient tool to counteract earlier problems being experienced again
- I appreciate Virtual Build as a work method to receive cross-functional feedback on my design solutions
- Misunderstandings in the communication are frequently experienced in projects

The following statements discuss concepts and concept development:

- I experience that the view of what "concept ready" means differ between the functions
- A finished concept contains detailed specifications
- During the yellow arrow, it is beneficial to keep the number of participants low

The following statements discuss assemblability, reparability and maintainability:

- My experience is the most important factor when assessing the level of assemblability
- DE has the main responsibility to ensure a high level of assemblability of components
- I use software to ensure the assemblability in my design solution

If your response was “Somewhat agree” or “Agree” on the above, please specify which one/ones below:

(room for free-text answer)

- How the work with physical and digital test assembly/disassembly is carried out in the projects depend on whom I work with

Part with yes/no questions

You will now be presented to a number of statements to which we want you to answer either:

“Yes”, *“No”* or *“Do not know”*.

- A clearer definition of what “concept ready” means would facilitate my work
- Innovation in the concept development is limited by early requirements at a detailed level
- More explicit requirements at component level would facilitate my work
- I prefer to have a continuous contact with other functions during the project
- I prefer that design decisions are taken at a few major milestones
- Assemblability is actively discussed at R&D
- Designing for repair and maintenance is actively discussed at R&D

Part with open-ended questions

Finally, you will be presented to four open questions, please answer as detailed as possible – you are the one with knowledge about this!

- At what stage of the NPD process would you like to receive detailed requirements from DE and YS?

  (room for free-text answer)

- How would you like to receive requirements from DE and YS in order to work with them in the best way? (verbally, written, digitally, etc.)

  (room for free-text answer)

- In what way do you think a cross-functional collaboration favours the design process?

  (room for free-text answer)

- When do you consider a concept as ready?

  (room for free-text answer)

If there is anything you would like to add, please write a line or two below:

(room for free-text answer)

A.1.1 The Coding of Data to Questionnaire Statements

Examples of how statements were created based on the data are found in Table A.1 below, in relation to the themes of "Balancing Requirements" and "Communication of Requirements". The same procedure was used when creating statements connected to the remaining three themes. The sources of information are anonymised but presented as numbers to show data came from several functions.

Table A.1 Examples of how questionnaire statements were derived.

Theme	***Statement***	***Example of comments leading up to the statements (anonymised)***	
Balancing Requirements	I am expected to take a major cross-functional responsibility for meeting the received requirements	"The engine assembly and the engine repair & maintenance communicate many demands and there are often contradictions between them" /Interviewee dept. 1	"The basis for balancing requirements is a unstructured mix of input from functions and deviation reports" /Interviewee dept. 2
	There exists a standardised method to balance between contradictory demands	"In some cases, conflicting requirements result in two different variants" /Interviewee dept. 2	"Priorities will depend on who pursues the project, although one should look to Scania as a whole" /Interviewee dept. 1
	When balancing demands, I prefer to support my decisions with requirements that can demonstrate positive financial results	"It will be easier for YS to get return on their demands if they can quantify their effect" /Interviewee dept. 3	"They (DE) have a strong voice since a change in the assembly can recoup so much money" /Interviewee dept. 4

Communication of Requirements	Requirements from DE/YS are mainly communicated through personal contact	"Communication of requirements works best when using personal channels" /Interviewee dept. 5	"Communication between parties during the project is mostly not formalised and personal contacts are important" /Interviewee dept. 2
	The production targets communicated by DE are hard to make use of in detailed designs	"Historically, DE has not performed well in formulating project specific objectives" /Interviewee dept. 6	"It is unclear exactly how production reveal their requirements" /Interviewee dept. 5
	Routines exist to provide feedback to the initiating demand provider of the requirements that cannot be met in the design	"The requirements sent are called "Wish List"" /Interviewee dept. 6	"Monitoring of requirements are mainly performed through deviation reports" /Interviewee dept. 2
	Requirements communicated from YS have a high level of influence on the design	"YS work to take a more active role in the development process, since they have realised that their demands were not always communicated" /Interviewee dept. 1	"An earlier involvement in the process has led to that the propositions from YS are taken into consideration to a higher extent" /Interviewee dept. 7
Communication	*The rest of the statements were created in the same way as above.*		
Concept			
Assemblability, Reparability and Maintainability			

A.2 Survey Results

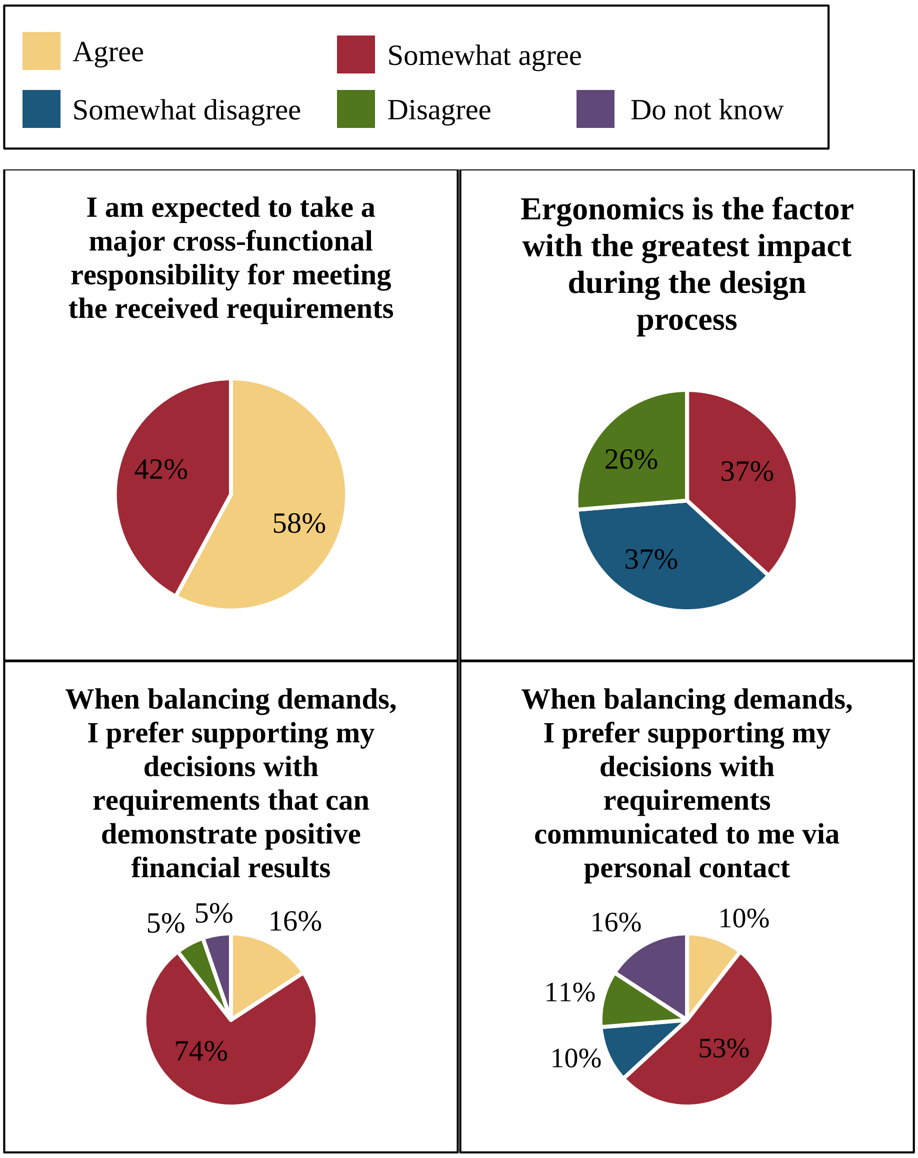
In the following section all results from the survey to design engineers are presented. The experience of the respondents varied as seen in Table A.2 below.

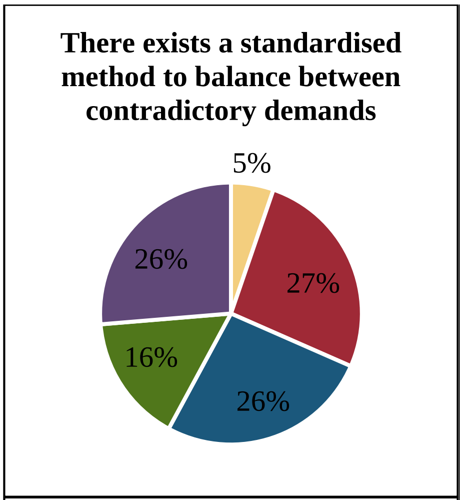
Table A.2 Years of experience of the respondents to the design engineer survey.

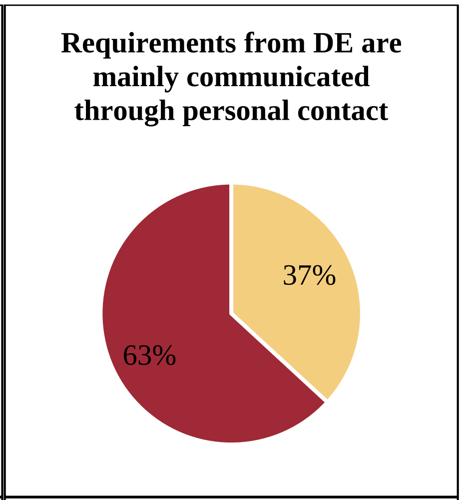
Respondent	*Years of experience as design engineer (at Scania)*	*Years of experience in Engine assembly (at Scania)*	*Years of experience in Engine repair and maintenance (at Scania)*
R1	5	0	0
R2	5	0	0
R3	8	8	0
R4	19	0	0
R5	8.5	0	0
R6	4	0	0
R7	10	0	0
R8	5	0	0
R9	21	1	0
R10	0.7916	0	0
R11	5	0	0
R12	10	0	0
R13	0.5	0	0
R14	3	0	0
R15	14	0	0
R16	0.5	0	0
R17	15	0	0
R18	37	0	0
R19	8	< 1	0

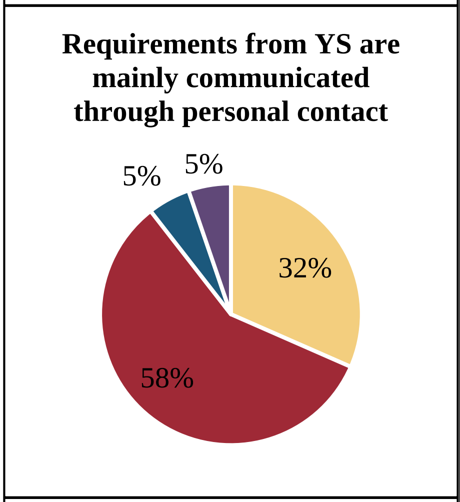
A.2.1 Close-Ended Questions: Statements

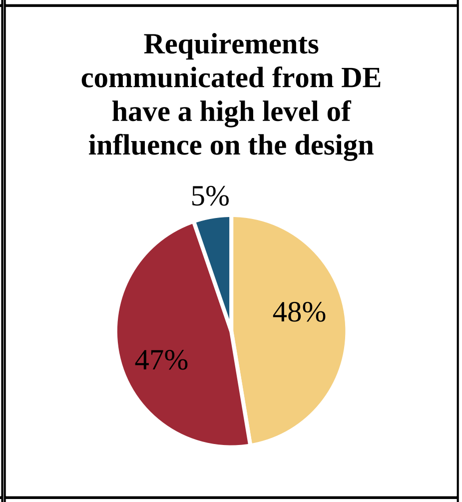
All results yielded from the statements with responds on the four-point scale.

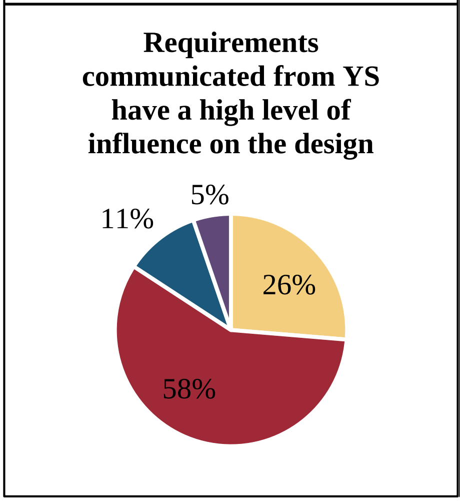


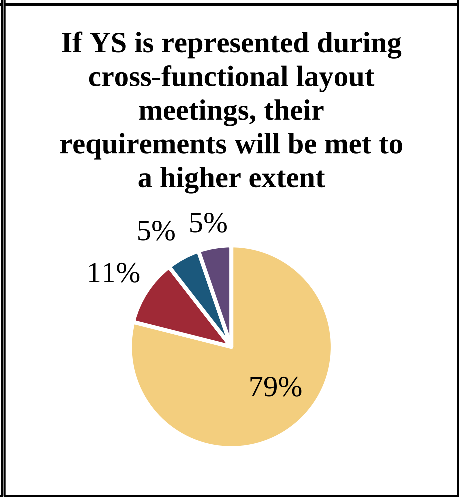

There exists a standardised method to balance between contradictory demands
5%
26%
27%
16%
26%


Requirements from DE are mainly communicated through personal contact
37%
63%

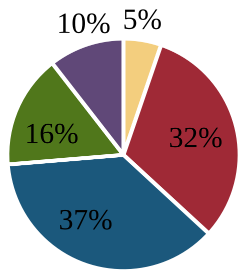

Requirements from YS are mainly communicated through personal contact
5%
5%
32%
58%


Requirements communicated from DE have a high level of influence on the design
5%
48%
47%

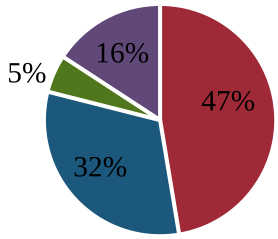

Requirements communicated from YS have a high level of influence on the design
5%
11%
26%
58%


If YS is represented during cross-functional layout meetings, their requirements will be met to a higher extent
5%
5%
11%
79%

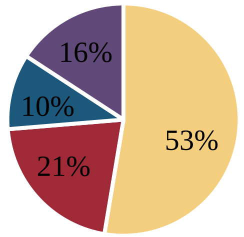
The production targets communicated by DE are hard to make use of in detailed designs



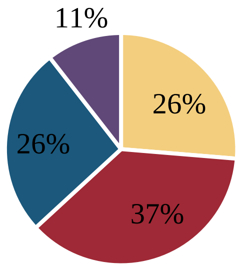
The product targets communicated by YS are hard to make use of in detailed designs



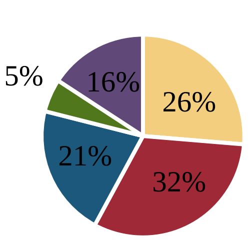
Communicated requirements often need to be further specified with the initiating part



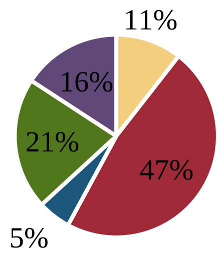
The project definition (PDf)/object definition (ODF) is used in the design process



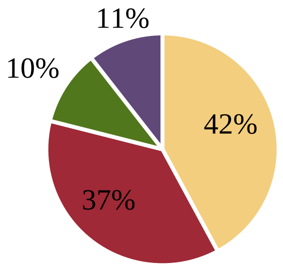
I find non-project specific “requirement lists” (e.g. DFA and SES) to be valuable tools in my design process



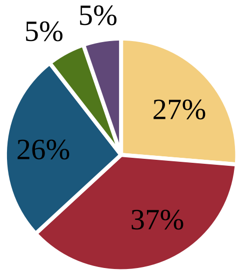
Routines exist to provide feedback to the initiating demand provider of the requirements that cannot be met in the design



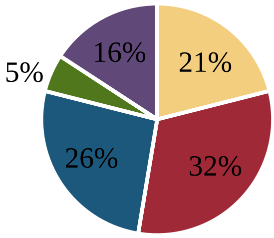
The input received from DE in the yellow arrow facilitates the design process



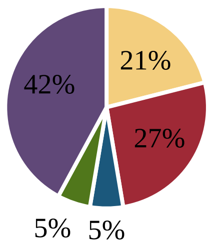
I experience a well-functioning support from DE throughout the design process



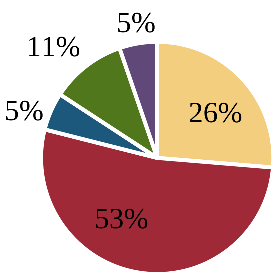
Lesson Learned is an efficient tool to counteract earlier problems being experienced again



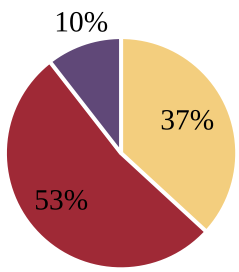
I appreciate Virtual Build as a work method to receive cross-functional feedback on my design solutions



Misunderstandings in the communication are frequently experienced in projects



I experience that the view of what “concept ready” means differ between the functions



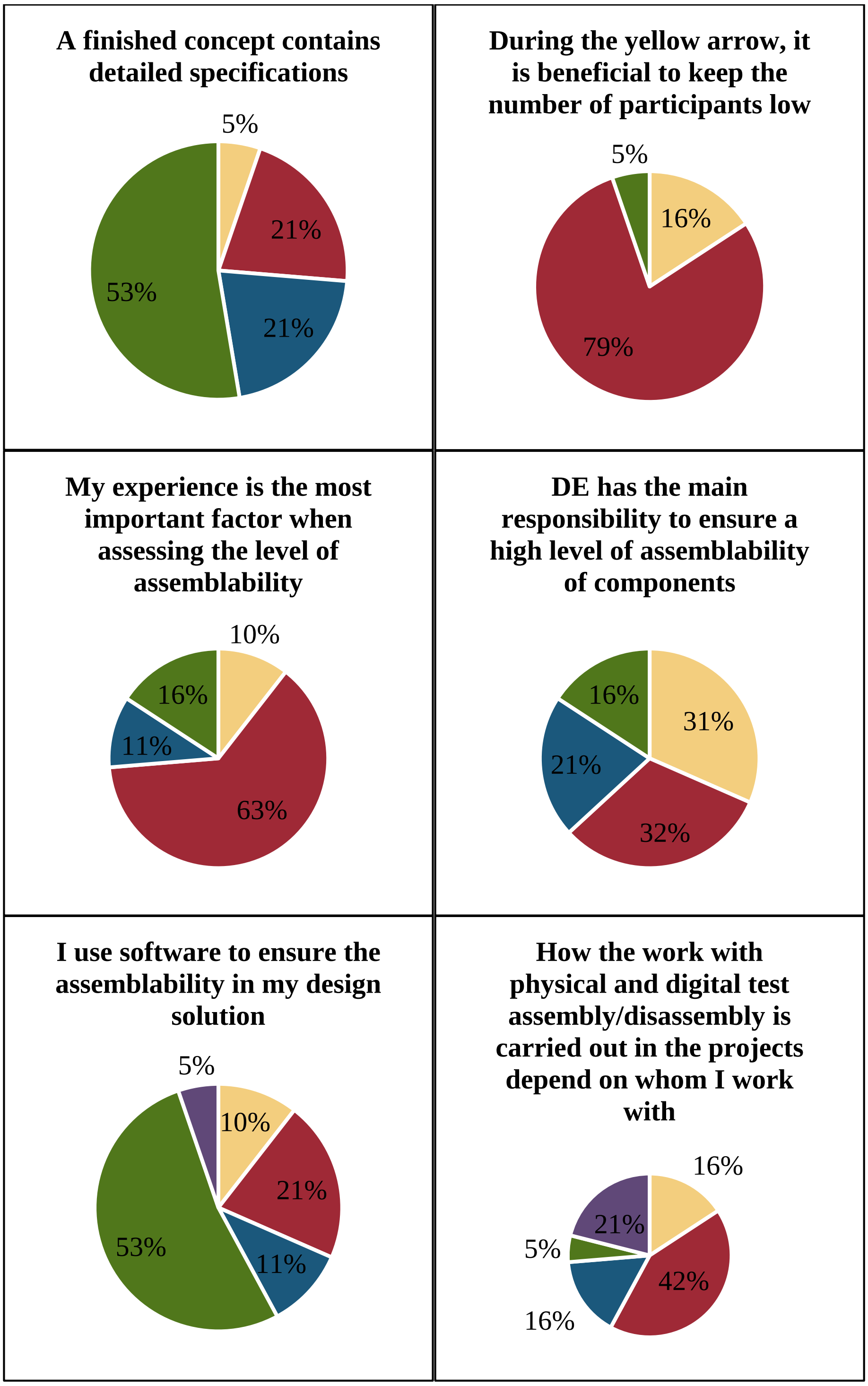


Figure A.1 The distribution of the responses to the close-ended questions in the questionnaire.

Free text answers

Below are all the free text answers related to the statements in theme 1-5.

Theme 1 – Balancing Requirements

Table A.3 Free text answers to the statement "Ergonomics is the factor with the greatest impact during the design process: Please specify which, in your opinion, is the most important factor in a decision situation", from the respondents (13 out of 13) that chose either the option "Disagree" or "Somewhat disagree" and from one respondent choosing "Somewhat agree".

Respondent	***Free text answer***
R1	/.../ Ergonomics (a requirement from the engine assembly) is extremely important and something we should take into account. But there are many other demands which are also important that we must consider when developing a product. For example, we cannot release a product that does not meet the requirements of solidity but is ergonomic to assemble. /.../
R4	Fuel consumption
R5	Manufacturability, performance, functionality, reliability (strength etcetera), assemblability and service precede ergonomics, but ergonomics is partly/largely included in the terms assemblability and service but unfortunately we do not design for ergonomics, it's more like a "bonus". We assume that the assembly and service solve heavy lifting etcetera with lifting tools etcetera.
R6	Balancing the requirements is the key.
R7	The main function
R8	The durability
R9	Function, strength, durability, cost
R10	The manufacturing
R11	Weight, strength
R12	Performance/consumption impact - right to the end customer
R14	/.../ What is the most important factor varies depending on the project, often factors such as robustness, fuel consumption and price highly prioritised.
R16	The functionality is always the most important, then one has to compromise sometimes.
R18	The function
R19	Life length

Table A.4 Free text answers to the statement "There exists a standardised method to balance between contradictory demands: Please specify which options you use", from the respondents (2 out of 6) that chose either the option "Agree" or "Somewhat agree" and from one respondent choosing "Somewhat disagree", two choosing "Disagree" and one the option "Do not know".

Respondent	***Free text answer***
R5	Unfortunately. We should have one, e.g. a so called Pugh matrix.
R6	Scania product properties, for example. To consider various concepts and compare them against each other by using cross-functions.
R9	Common sense
R11	Fuel consumption - the allowed cost of a weight reduction
R15	Balancing requirements
R18	The method varies with the problem.

Theme 2 – Communication of Requirements

Table A.5 Free text answer to the statements "Requirements from DE/YS are mainly communicated through personal contact: Please specify how requirements are communicated". Only one response did not agree to this and chose the option "Somewhat disagree".

Respondent	***Free text answer***
R18	During presentations, e.g. design reviews

Table A.6 Free text answers to the statement "I find non-project specific "requirement lists" (e.g. DFA and SES) to be valuable in my design process: Please specify which documents you are using and you opinion about them", from the respondents (5 out of 8) that chose either the option "Agree" or "Somewhat agree".

Respondent	***Free text answer***
R1	I have been using the SES document. In my opinion, it is difficult to translate it into designs and it is also a bit too extensive.
R6	I have recently started to look in SES and it works great.
R7	The evaluation template SES according to STD4323.
R13	SES - a good checklist to capture details that can be easily missed.
R19	The group's own Design Guidelines for each component.

Theme 5 – Assemblability, Reparability and Maintainability

Table A.7 Free text answers to the statement “I use software to ensure the assemblability in my design solution: Please specify which one/ones below”, from the respondents (6 out of 6) that chose either the option “Agree” or “Somewhat agree” and from two respondents choosing “Disagree”.

Respondent	***Free text answer***
R4	The model library of wrenches and tools in Catia Enovia
R5	I use Catia V5
R6	Catia
R7	CATIA
R9	It is the design engineer’s responsibility that the component can be assembled.
R10	CATIA
R16	The main interest of the design function is a product with good functionality, if you want to have a high level of assemblability, experts in the field must be involved since they have more knowledge about the assembly possibilities.
R18	Catia

A.2.2 Yes/No Questions

The respondents’ responses of the yes/no questions are presented in Figure A.2 below.

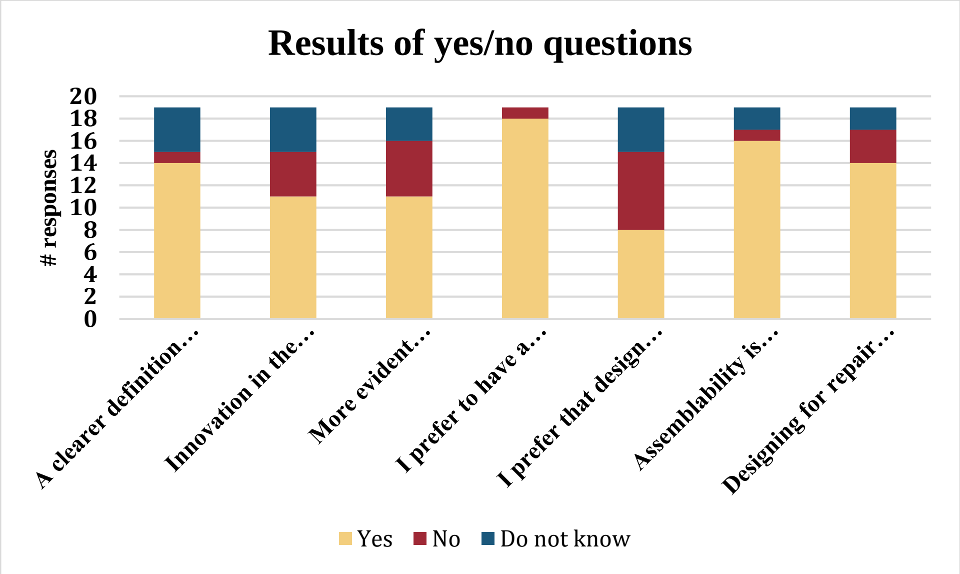


Figure A.1 The responses to the yes/no questions in the questionnaire. The full-length questions have been presented earlier in Section A.1

A.2.3 Open-Ended Questions

Most of the respondents provided an answer to all the questions and their free text answers to the first two questions can be found in Table A.8 and to the other two in Table A.9. For the reader's convenience, the questions are repeated below.

- Question 1: "At what stage of the NPD process would you like to receive detailed requirements from DE and YS?"
- Question 2: "How would you like to receive requirements from DE and YS in order to work with them in the best way? (verbally, written, digitally, etc.)"
- Question 3: "In what way do you think a cross-functional collaboration favours the design process?"
- Question 4: "When do you consider a concept as ready?"

Table A.8 Free text answers to the first two open-ended questions in the questionnaire.

Respondent	*Free text answer Question 1*	*Free text answer Question 2*
R1	During the yellow arrow (before the concept is considered ready). As the conditions change throughout the project, I also think that it is very important that both DE and YS are involved during the entire process, for example actively involved in the layout of meetings and design reviews. This so that demands from the functions do not enter late in the project when the design is almost or completely set.	Verbally during layout meetings, design reviews and design freeze sessions. Also written, through personal contact via mail, works well.
R2	Green arrow configuration, in yellow arrow general guidelines	IRL, with the opportunity to discuss/understand the meaning of the requirements
R3	As today, continuous input from DE/YS during layout meetings	As today, via layout meetings. In the ways through which they (note: the requirements) can be quickly anchored in order to continue.
R4	At the F2-generation	Design reviews in several steps
R5	ASAP	In every way
R6	Well before the CR-1	In all of them
R7	As early as possible, preferably before the first test assembly of the first prototype.	In every way. Formally written and digital. Personal meeting to talk.
R8	-	Digitally
R9	Most of the requirements should have been given as input when the project enters the green arrow.	“Face to face” + written
R10	I do not have experience of the so-called “early” stage of PD, extinguishing fires.	Verbally and digitally
R11	If they have any requirements they should enter early in the NPD process. As by now, they rarely have any requirements for my components.	Written demands

R12	During the yellow arrow process.	Preferably in document form and an oral communication
R13	-	Written, but supported by a verbal briefing if necessary.
R14	Early. Feedback on the concepts regarding requirements should normally come as early as possible.	Early in the development process, the best way of communicating is through dialogues at layout meetings etcetera. Later in the process, when there is a higher level of detail, I usually book test assemblies with simple prototypes (like FFF) in order to test solutions.
R15	In the start	Written
R16	-	-
R17	During the green arrow	Verbally
R18	In the beginning and not in the form “10 % shorter service time”.	General requirements in written form, and personal meetings.
R19	During the development of the F1 generation.	Written

Table A.9 Free text answers to open-ended questions number three and four in the questionnaire.

Respondent	*Free text answer Question 3*	*Free text answer Question 4*
R1	It is very important that the cross-functional process works well since it results in a good product. It is important that communication between the design engineer and the cross functions are good and that all cross functions work with synchronised schedules. By this, the design engineer will have opportunity to take all the requirements into account.	I think the concept is ready when the yellow arrow is finished. This means we must have an anchored and tested concept that we know will work. Thereafter, when we enter the green arrow, the detailed design can be initiated and some changes be made.
R2	(It) creates an understanding of all customers’ needs, even internal customers’.	Concept is geometrically proven, feature virtually verified. Hardware not yet tested.
R3	Shorter lead-times in the development process.	When you have a completed 3D model that meets “everyone’s” wishes.

R4	We are reaching the right solution more quickly.	There is a difference between concept and detailed solutions. Flexibility is needed, provided it is possible to change the solution and have time enough to verify in time for the start of production.
R5	It is the foundation in our way of working.	When there is a concept that fits, has the right performance, is possible to service and is reasonably solid.
R6	Designing is all about balancing. Cooperation of all cross functions creates better conditions for wise decisions.	Complex question
R7	The more perspectives, the better the design.	When I know the main function can be fulfilled, that the concept can be produced, built and serviced. When the price and weight are OK.
R8	-	-
R9	It is more efficient	When the function/functions of the component is/are secured.
R10	Even more “right from me” (well thought-out and really good) designs leave the design engineer.	When sent in PR status (note: an indication of the drawing’s readiness, when the status is reached investments in tools can be initiated)
R11	-	When you agree that this is what we are pursuing.
R12	It is a pre-requisite for achieving a good result.	It varies with the size of the project and phase. 3D models are finished and the concept being cross-functionally anchored can be important.
R13	Less risk that important aspects are lost.	When there is a clear idea that all involved parties consider to work.
R14	The way I see it, the aim of the design process is to develop a solution that meets the defined requirements. Without any form of cross-functionality, the design engineer is left to his/her own idea of how his/her product meets the requirements. My experience is that this view, at best, is limited to experience, and at worst, to ill-founded prejudices. Thus, some cross-functionality is required in order to achieve a high quality.	This is a question of judgment in each individual case. However, one should be able to have as a guideline that the concept is considered complete when it describes a solution to the entire requirement specification.

R15	(It) saves work	Technical concept is ready
R16	Different departments have different expertise and values. With a cross-functional group, many problems related to machining, assembly and so on, can be noted in time and by his one can reduce the extra work.	After one has evaluated various solutions, compared them and managed to demonstrate that this will likely work.
R17	Correct from the beginning	When the layout is frozen
R18	An early correct input results in shorter development times and better quality.	When you know how the items will look in detail.
R19	(It is) very good to get input from all who might be affected by the design.	Once the prototype has been developed and tests have shown that the function is what was intended.

Appendix B Survey to Line Assemblers

The survey to line assemblers was created from information collected during participant observation of the engine assembly process. It was distributed to 16 respondents from three different assembly areas on the engine assembly lines at Scania Södertälje. The response rate was 100 % with the exception of one respondent not answering the last two questions.

B.1 The Survey

Below is a translated version of the survey. It was originally written and distributed in Swedish.

1. Process and product are designed so that it is easy to assemble correctly

No, great job skills are required	1	2	3	4	5	6	Yes, doing right is easy

2. An understanding of how the engine function is important to assemble correctly

No, an understanding is not necessary	1	2	3	4	5	6	Yes, deep understanding is necessary

3. Following the standards in the element sheet is important to assemble correctly

No, standards are primarily guidelines	1	2	3	4	5	6	Yes, standards should be followed in detail

4. The ergonomics of my area is good

No, ergonomics should be enhanced	1	2	3	4	5	6	Yes, ergonomics is good

5. Improvement suggestions from assemblers regarding product quality have great impact

No, suggestions are never realised	1	2	3	4	5	6	Yes, suggestions are often realised

6. Improvement suggestions from assemblers regarding ergonomics have great impact

No, suggestions are never realised	1	2	3	4	5	6	Yes, suggestions are often realised

7. I feel well prepared to handle new engine variants when they are introduced

No, I'd like to be better prepared	1	2	3	4	5	6	Yes, I always feel well prepared

8. Upon introduction of new engine variants, tools and equipment are installed

No, the line is rarely prepared	1	2	3	4	5	6	Yes, the line is always prepared

9. There is a well-tuned collaboration between the logistics process and the assembly process

No, the collaboration can be improved	1	2	3	4	5	6	Yes, the collaboration is well-tuned

10. Automated variant proofing equipment (e.g. scanners and cameras) work efficiently to eliminate deviations

No, equipment complicates the process	1	2	3	4	5	6	Yes, equipment works efficiently

11. Visual aids for variant proofing (e.g. colour coding and pick-to-light) facilitate the assembly process

No, they are often unnecessary	1	2	3	4	5	6	Yes, they are great facilitators

12. A high level of standardisation among engine variants is important for an efficient assembly process

No, standardisation is not important	1	2	3	4	5	6	Yes, standardisation is very important

13. The greatest advantages with the engine assembly process today are (select up to 3 alternatives)

- ☐ Ergonomic work environment
- ☐ Well-balanced line
- ☐ Good use of IPV equipment
- ☐ Good use of visual indicators
- ☐ Well-tuned collaboration with logistics
- ☐ Varying assembly tasks
- ☐ Good product introduction preparations
- ☐ Standardised methods

- ☐ Possibility to drive changes in the area
- ☐ Thought-through assembly order
- ☐ Good collaboration within the area
- ☐ Other: ______________________

14. The greatest disadvantages with the engine assembly process today are (select up to 3 alternatives)

- ☐ Non-ergonomic work environment
- ☐ Uneven workload between stations
- ☐ Time-consuming/inefficient IPV equipment
- ☐ Time-consuming/inefficient manual variant proofing
- ☐ Large risk of picking wrong components
- ☐ Repetitive work
- ☐ New engine introductions are often problematic
- ☐ Too many working moments to learn
- ☐ Little possibility to change my work situation
- ☐ Many working moments feel unnecessary
- ☐ Collaboration difficulties within the area
- ☐ Other: ________________________

B.2 Results from Questions 1-12

The first twelve questions (statements) were rated on a six-point interval scale by the respondents, where a higher number meant stronger agreement with the statement. Mean value and variance for each statement are presented in Table B.1.

Table B.1 Results for the first twelve statements. Sample means and sample variances are the collective results for all three areas.

Statement	*Mean Area 1*	*Mean Area 2*	*Mean Area 5*	*Sample mean*	*Sample variance*
Process and product are designed so that it is easy to assemble correctly	5.00	4.33	4.60	4.63	1.98
An understanding of how the engine function is important to assemble correctly	3.20	2.33	4.00	3.13	1.85
Following the standards in the element sheet is important to assemble correctly	4.60	4.67	5.60	4.94	1.80
The ergonomics of my area is good	3.60	3.17	4.80	3.81	2.03
Improvement suggestions from assemblers regarding product quality have great impact	3.80	3.00	3.80	3.50	2.27
Improvement suggestions from assemblers regarding ergonomics have great impact	3.60	3.00	3.80	3.44	2.26
I feel well prepared to handle new engine variants when they are introduced	5.20	4.33	3.60	4.38	2.12
Upon introduction of new engine variants, tools and equipment are installed	4.80	3.50	4.60	4.25	2.73
There is a well-tuned collaboration between the logistics process and the assembly process	4.80	3.17	4.80	4.19	2.96
Automated variant proofing equipment (e.g. scanners and cameras) work efficiently to eliminate deviations	4.80	3.83	5.20	4.56	1.46
Visual aids for variant proofing (e.g. colour coding and pick-to-light) facilitate the assembly process	5.40	4.00	4.80	4.69	1.30
A high level of standardisation among engine variants is important for an efficient assembly process	5.20	4.17	5.80	5.00	0.93

B.3 Results from Questions 13-14

Questions 13 and 14 were of the type multiple choice multiple select. The results, based on 15 respondents, are presented in Figure B.1 and Figure B.2.

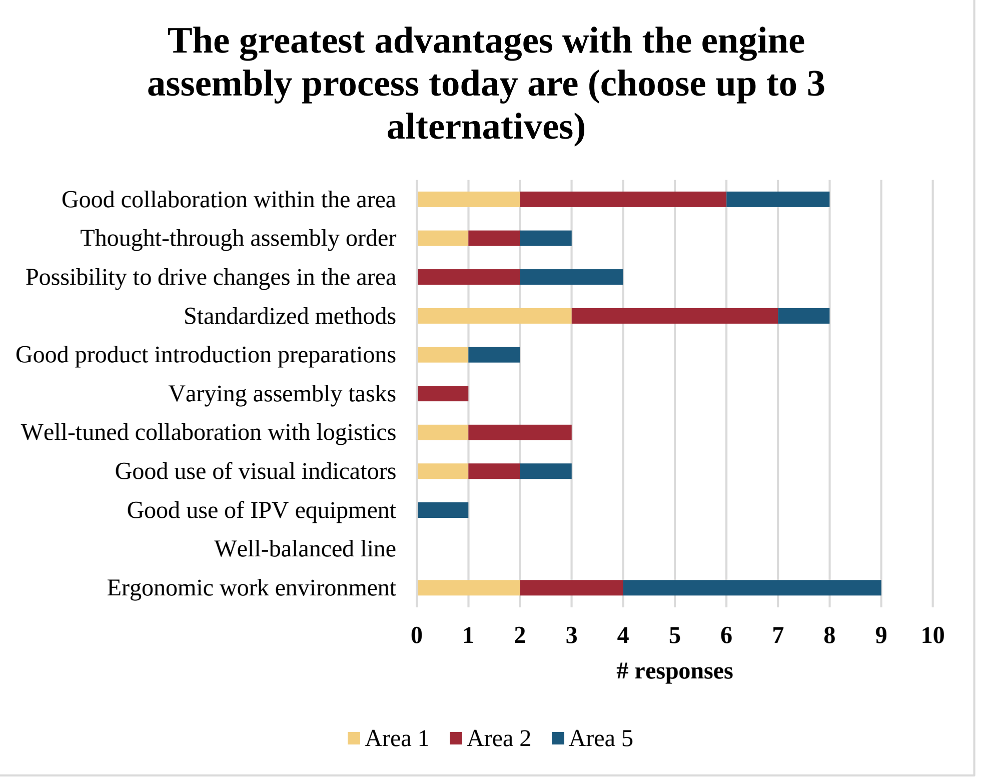


Figure B.1 Advantages with the assembly process.

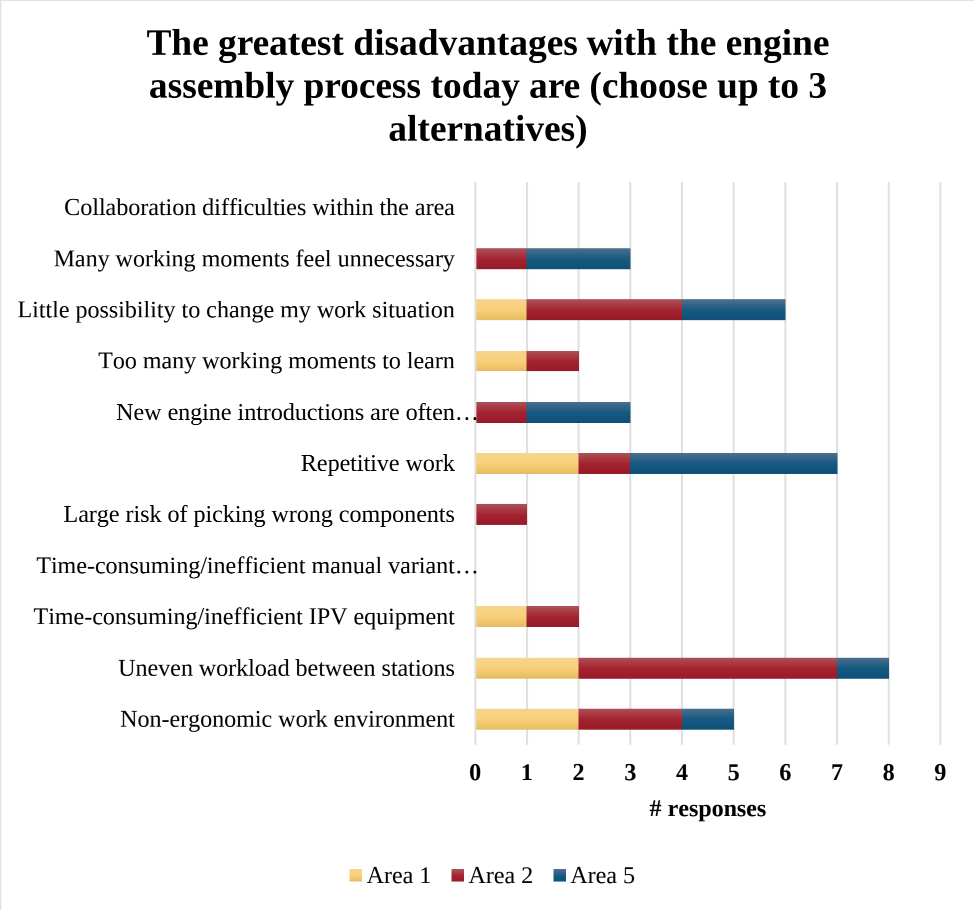


Figure B.2 Disadvantages with the assembly process.

Appendix C Organisational Information

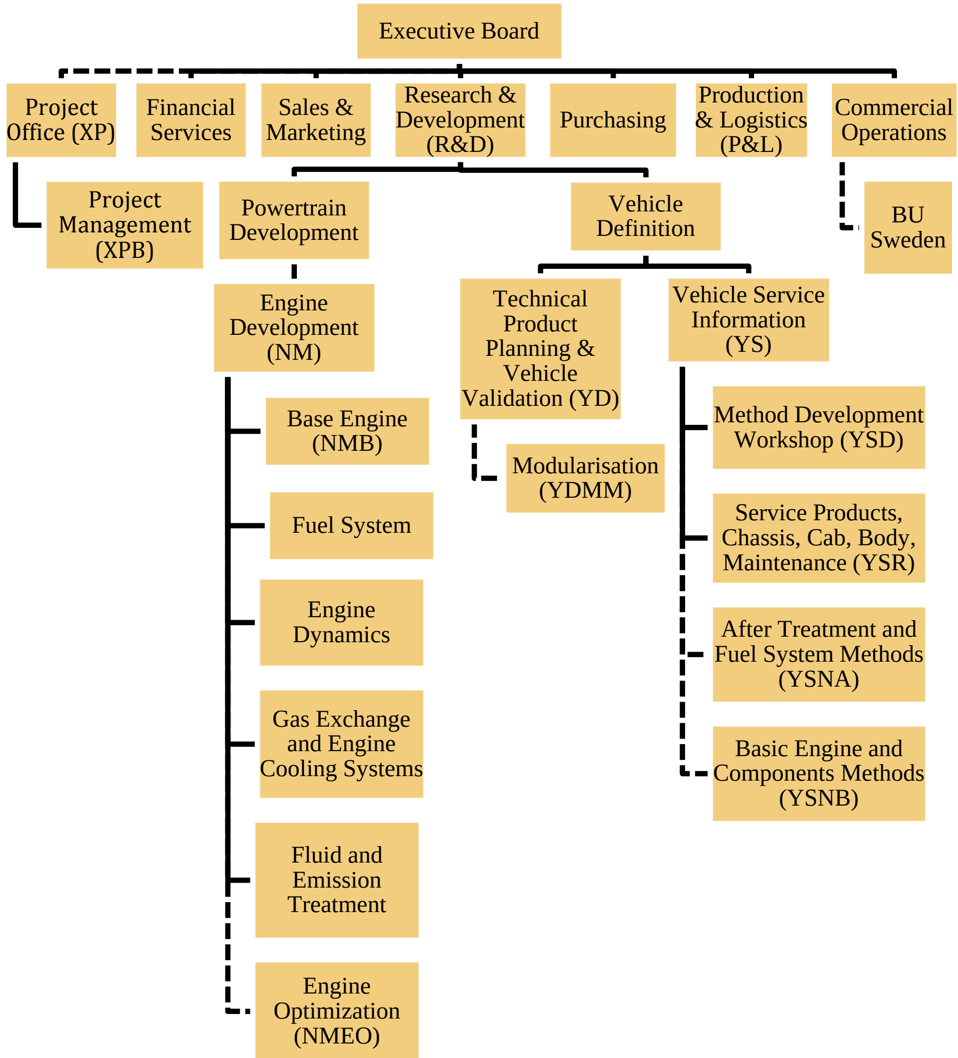


Figure C.1 Organisational chart of Scania. The sub-ordinate functions of P&L are provided in a separate figure. Note that only those functions targeted in the study are included.

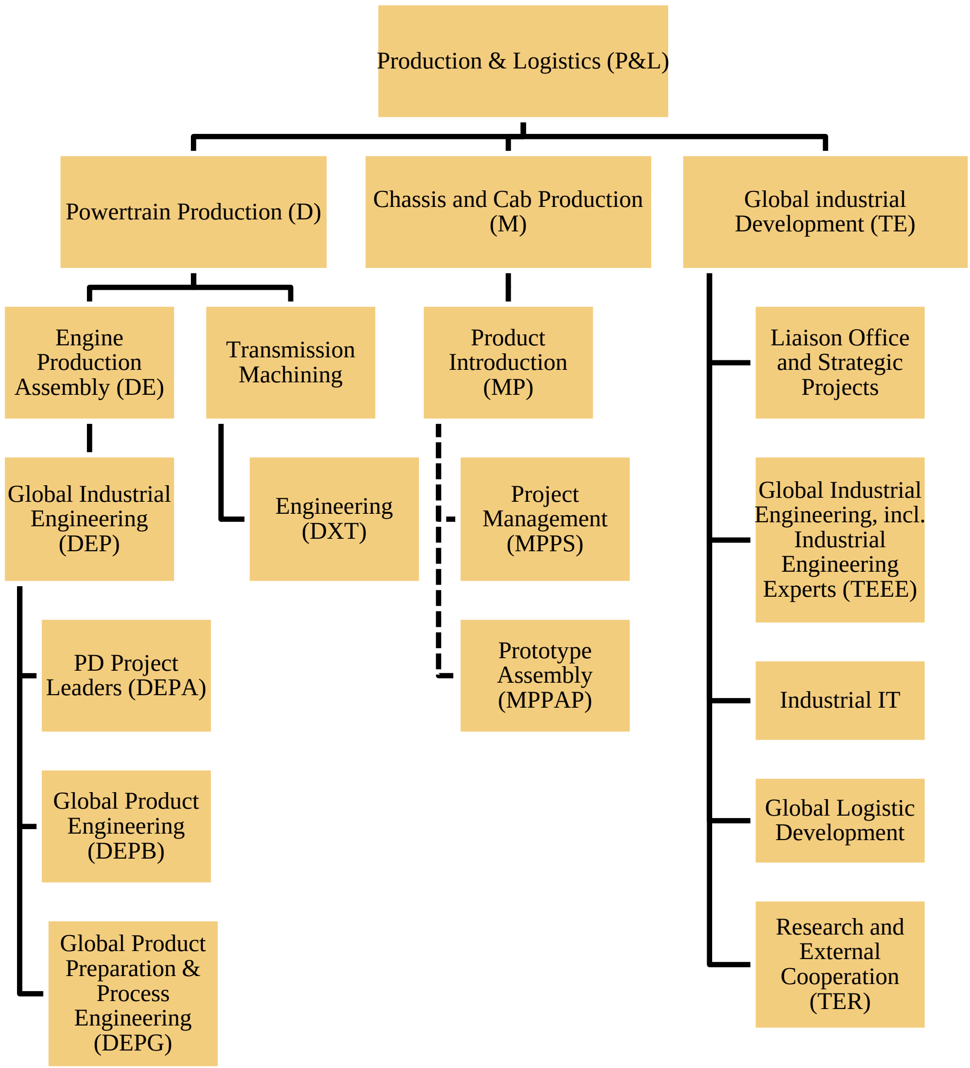


Figure C.2 Organisational chart of the P&L function. Note that only those functions targeted in the study are included.

Appendix D Interview Guides

D.1 Pre-Study

Due to the varying nature of the pre-study interviews, interview guides did not follow the same pattern. Many questions also aimed to increase the authors' knowledge about the new product development process and Scania in general, and are therefore not presented below. Below is however provided examples of questions from the interview guides leading up to further investigation and formulation of research questions:

- Would you like to tell us about your role as *interviewee title* and your department?
- How is product introduction conducted?
- Is the current process well established at your and other departments?
- Which activities in the process do you regard as the most value creating?
- How would you like the competence from the production function to be integrated into the process?
- How is the input from product introduction departments considered in the process?
- Where can the engine assembly function provide input to the process?
- How is the function DE structured?
- How is product introduction connected to project managers? Who is responsible for the activities?
- How are products evaluated in the digital and physical tests?
- What happens when deviations occur in the development process?
- How are product targets or requirements set?
- On which basis are requirements balanced against each other if a trade-off situation occur?

D.2 Semi-Structured Interviews

The following questions appeared in all interview guides, although sometimes in different order or slightly rephrased:

- Would you like to tell us about your role as *interviewee title* and your department?
- Can you describe the product development process from your perspective?
    - When does your work begin and end in the process?
    - Which steps are performed?
    - Which are your responsibilities?
- Which other departments do you have the most contact with during the process?
    - How do you collaborate with them?
    - How do you communicate with them?
    - Who initiates the contact?
- (for external stakeholder interviewees) Which input do you enter to the process?
    - How do you feel your input is considered?
- (for design engineers and project managers) When does input from involved functions enter the process?
    - How do you perceive the input? Are requirements easy to understand and use?
    - Which feedback is given to those providing input?
- (for design engineers and project managers) How are requirements balanced against each other in a trade-off situation? By whom?
- How do you work with Lessons Learned?
- (one or more of the following) How would you describe a product perfectly adapted to production? Assembly? Disassembly? How well do you think Scania engines are adapted to assembly? Service?
- Which are in your opinion the greatest advantages and disadvantages with the product development process as it is today?
    - Have you noticed any changes in the process over the past years?

The following questions appear in one or a few interviews:

- (to YD) At which stage is detailed design performed?
- (to YD, XP) How does the transfer between concept and product development work?
- (to YD, XP) How do you perceive the different functions and their role during the development process?
- (to XP, NM) Who initiates digital and physical tests?
- (to NM) How are engines or larger projects broken down to component level during development and who in responsible for the interfaces between them?
- (to NM) Do you think innovation is encouraged during development process and where does it typically come from?
- (to NM) At which stage is the design frozen?
- (to DE) How is your relation to the service/aftermarket function?

- (to DE) How can innovation in product development projects be driven from the assembly function?
- (to YS) How do you perceive the distribution of responsibilities during the development process?
- (to YS) Can you explain a digital test disassembly? Are these performed in every project?
- (to YS) Can you explain the R&M contracts Scania offers customers today?
- (to YS) How is your relation to the engine assembly function?

D.3 Engine Assembly Focus Group

Discussion questions for the engine assembly focus group:

- What do you associate with the word assemblability?
- Is assemblability something you reflect upon yourself or often discuss at you department?
- In which situations do you most commonly experience difficulties related to assembly, because of product properties?
- How would you describe an engine which is perfectly adapted to assembly, from your own perspective?
- Which factors do you think affect how easy a product is to introduce?
- Do you have examples of introduction projects where the product has well- or less well-adapted to assembly?

Exercise in two groups:

- Write attributes (one-liners) of the product or product development process which facilitate or hinder your work, or facilitate or hinder the work of other functions. Place these on a two-dimensional graph indicating the degree of facilitation/hindrance for you and other functions.

D.4 Engine Repair and Maintenance Focus Group

Discussion questions for the engine repair and maintenance focus group are presented below. The term directly translated to "serviceability" is here exchanged for "reparability and maintainability".

- What do you associate with the words reparability and maintainability?
- Is reparability and maintainability something you reflect upon yourself or often discuss at your department?
- How would you describe an engine which is perfectly adapted to service?

- Which are in your opinion the greatest challenges with engine maintenance and repair?
- How do you think service aspects should be considered during the product development process?
- Do you have examples of engine development projects resulting in good or less good reparability and maintainability of the resulting product?
- How do you think good reparability and maintainability contribute in creating value for the end customer and Scania as a whole?

Appendix E Work Distribution and Time Plan

E.1 Time Plan and Performed Activities

The initial project plan, as decided upon during the pre-study, is provided in Figure E.1. Although activities and the duration of activities were decided upon in the early phases, changes were made during the study and the performed activities, see Figure E.2, differ from the original project plan in several aspects. The largest difference is the exclusion of the case study and the extension of the raw data collection period to include identification of critical factors as well as external stakeholder expectations. Although the schedule was allowed to be flexible the two largest milestones, the end of the data collection period in mid-April and the hand-in of the report, were practically fixed and guided the scheduling of other activities.

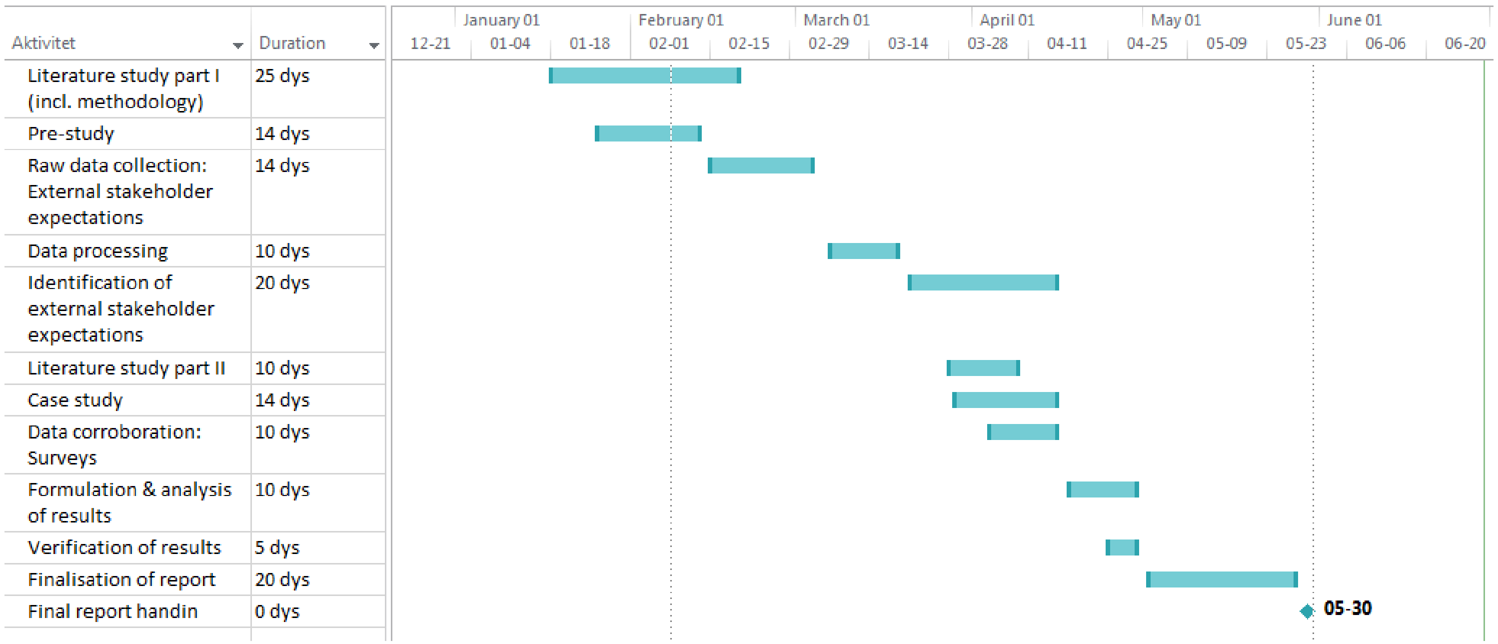


Figure E.1 Project plan.

Aktivitet	Duration
Literature study part I	20 dys
Pre-study	14 dys
Raw data collection	39 dys
Observation assembly line	2 dys
Focus group assembly	0 dys
Observation VB meeting	0 dys
Observation PPM	0 dys
Observation service workshop	0 dys
Focus group R&M	0 dys
Verification of material from interviews	10 dys
Data processing	20 dys
Data corroboration: Surveys	20 dys
Literature study part II	20 dys
Formulation & analysis of results	15 dys
Verification of results	1 dy
Finalisation of report	12 dys
Report handin	0 dys

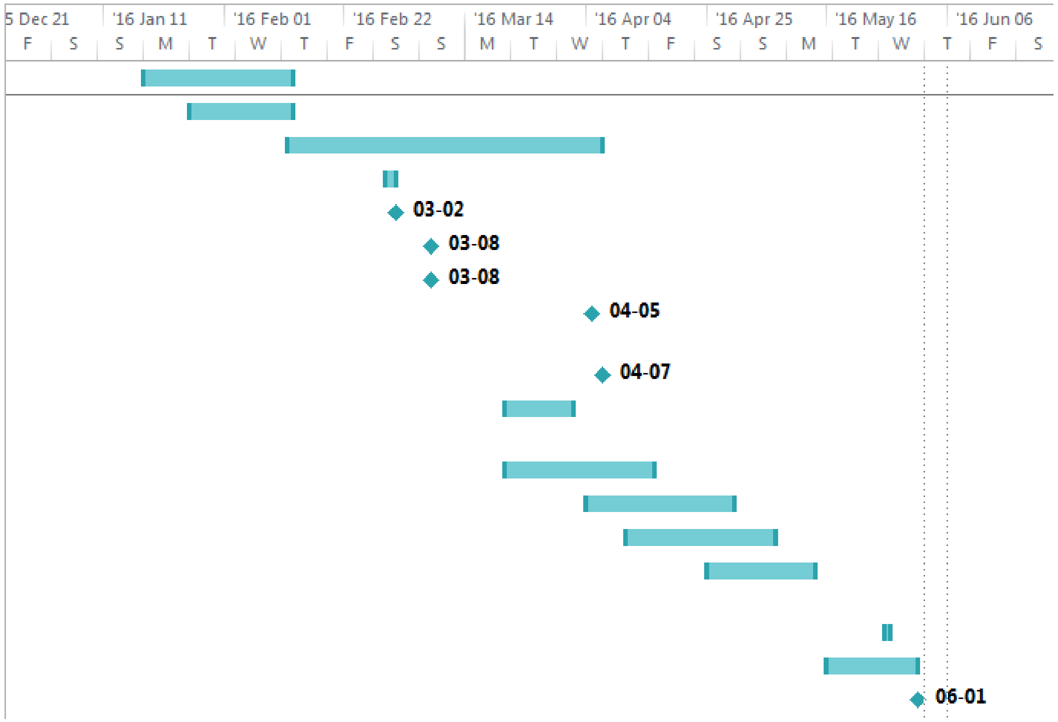


Figure E.2 Performed activities.

E.2 Work Distribution

The responsibilities of the two authors for each performed activity are listed in Table E.1 together with the division of the work load. Although most tasks were assigned as the responsibility of one author only, all important matters were discussed together to ensure streamlined cooperation during the project. This is especially true for the formulation of the results.

Table E.1 Division of work between the authors during the thesis project.

Activity	*Work load in % (Cederberg/Enarson)*	*Responsibilities of authors*
Literature study part I	50/50	Shared
Pre-study	50/50	Shared
Raw data collection	55/45	Shared: Interviews, focus groups, observations and document study Cederberg: Preparation of focus group material Enarson: Identification of key informants, compilations
Verification of material from interviews	50/50	Cederberg: Verification of extracted material for further analysis Enarson: Verification of material, quotes and comments for inclusion in report
Data processing	60/40	Shared: Transcription Cederberg: Extraction and first level of coding Enarson: Second level of coding (themes)
Data corroboration: Surveys	35/65	Cederberg: Line assembler survey Enarson: Design engineer survey incl. pre-testing
Literature study part II	50/50	Cederberg: LPD, DFA, DFS Enarson: OL, integration over functional interfaces in PD
Formulation and analysis of results	50/50	Cederberg: External stakeholder expectations Enarson: Influential and contextual factors
Verification of results	50/50	Shared
Finalisation of report	50/50	Shared