Innovation Management & Simulations

Early innovative product exploration with modern working methods and technical simulations

Ebba Blomberg Cedergren & Linnéa Härder

DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS

Innovation Management and Simulations

Early innovative product exploration with modern working methods and technical simulations

Innovationshantering och simuleringar - Tidig
innovativ produktprospektering med moderna arbetssätt och tekniska simuleringar

Ebba Blomberg Cedergren & Linnéa Härder

LUND UNIVERSITY

Innovation Management and Simulations - Early innovative product exploration with modern working methods and technical simulations

Innovationshantering och simuleringar - Tidig innovativ produktprospektering med moderna arbetssätt och tekniska simuleringar

Published by
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Publicerad av
Institutionen för designvetenskaper
Lunds Tekniska Högskola, Lunds universitet
Box 118, 221 00 Lund

Subject: Product Development (MMKM05)
Division: Division of Product Development, Department of Design Sciences, Faculty of Engineering LTH, Lund University
Supervisor: Damien Motte
Co-supervisor: Håkan Petersson
Examiner: Axel Nordin

Ämne: Produktutveckling (MMKM05)
Avdelning: Avdelning för Produktutveckling, Institutionen för Designvetenskaper, Lunds Tekniska Högskola, Lunds Universitet
Huvudhandledare: Damien Motte
Bitr. handledare: Håkan Petersson
Examinator: Axel Nordin

"If I find 10,000 ways of something won't work, I haven't failed. I am not discouraged, because every wrong attempt discarded is another step forward."

- *Thomas Edison*

Abstract

The shortening of the development lead time for products is heavily affecting the need for having a strategic approach to product development methodology. It is also of the utmost importance to use the right tools and have an understanding concerning the digitalization of the industry. Presented in this Master Thesis, conducted after an incitement from Scania, is a strategic approach towards a modern product concept development and how technical simulations can be used as a tool to speed up the processing time. The area of investigation is limited to the Research & Development department RT and the suggested activities of change will be concerning the current processes at the focus company. The Master Thesis was performed through a case study at Scania, a literature review from published resources and a minor benchmarking to aim for generalized results.

The results show that the use of technical simulations works as an efficient resource tool when implementing a modern product concept development with an Agile focus for both the design and simulation engineer. The supportive aspect comes from the fact that the tool could be used iteratively, handle continuous changes, provides a holistic approach as well as system thinking.

Three main difficulties were retrieved within the current process at Scania, such as lack of explorative space, unclear definition of a concept as well as a process that is too slow. The activity of change would be to implement an extra process step in the current concept development strategy at Scania as well as using digital demonstrators as concepts. Difficulties within the organisation were found with the role of the design engineer and the lack of collaboration between test and simulation engineers. The solutions presented concerning the organisation would be to rework the current role of the design engineer and change the way of communicating between design, simulation, and test groups.

Keywords: Technical Simulations, Product Concept Development, Exploration, Agile Methods, Simulation Driven Development

Sammanfattning

Förkortningen av ledtiden för utveckling av produkter påverkar kraftigt behovet av att ha ett strategiskt tillvägagångssätt för produktutvecklingsmetodik. Det är också av yttersta vikt att använda rätt verktyg och ha förståelse för digitaliseringen av industrin. I denna uppsats, som utförs efter en förfrågan från Scania, presenteras ett strategiskt tillvägagångssätt mot en modern produktkonceptutveckling och hur tekniska simuleringar kan användas som ett verktyg för att påskynda processen. Undersökningsområdet är begränsat till Forskning- och Utvecklingsavdelningen RT och de föreslagna förändringsåtgärderna kommer att vara i förhållande till aktuella processer hos fokusföretaget. Examensarbetet genomfördes genom en fallstudie vid Scania, litteraturstudie av publicerade artiklar och en mindre benchmarking för att sträva efter generaliserade resultat.

Resultaten visar att användningen av tekniska simuleringar fungerar som ett effektivt resursverktyg när man implementerar modern produktkonceptutveckling för både konstruktör och beräkningsingenjör. Den stödjande aspekten härrör från det faktum att verktyget kan användas iterativt, hantera kontinuerliga förändringar, ge en helhetssyn samt underlätta systemtänkande.

Tre svårigheter hittades inom den nuvarande processen på Scania, såsom brist på explorativ rymd, otydlig definition av koncept samt en process som är för långsam. Verksamhetsändringen skulle vara att införa ett extra processteg i den nuvarande konceptutvecklingsstrategin på Scania samt använda digitala demonstratorer som koncept. Svårigheter inom organisationen hittades med konstruktörens roll och bristen på samarbete mellan test- och beräkningsingenjörer. Lösning presenterad i förhållande till organisationen skulle vara att omarbeta konstruktörens nuvarande roll och ändra sättet att kommunicera mellan konstruktörs-, beräknings- och testgrupper.

Nyckelord: Tekniska Simuleringar, Produktkonceptutveckling, Explorering, Agila metoder, Simuleringsdriven Utveckling

Acknowledgments

First, we would like to thank our supervisor at Scania, Kent R Johansson for making this Master Thesis possible and for believing in us. For being there to guide us and answer our questions every time. We also want to thank the steering group at Scania, which consisted of Mikael Thellner, Anton Wieselblad, Ola Brantefors, Ingela Muhrbeck, and Olov Petrén as well as everyone who has contributed to the making of this Master Thesis.

We are grateful for the support and guidance that our supervisors, Damien Motte, Lund University, and Håkan Petersson, Halmstad University, have given us. We also like to thank Tobias Larsson at Blekinge Institute of Technology, for helping us with literature.

The journey has been challenging, constantly pushing us to perform at our best. The experience has developed our skills to communicate and cooperate and is of significant value for our future working life. We are now ready to face new challenges!

Lund, June 2019

Ebba Blomberg Cedergren & Linnéa Härder

Table of Contents

List of Acronyms & Abbreviations

AD – Assignment Directive

AM – Additive Manufacturing

CAD – Computer Aided Design

CAE – Computer Aided Engineering

CAM – Computer Aided Manufacturing

CBDA – Computer Based Design Analysis

CE – Concurrent Engineering

CFD – Computational Fluid Dynamics

CQ – Concept Portfolio Meeting

CR-1 – Concept Review Minus One

DMU – Digital Mock-up

DP – Decision Point(s)

DSDM – Dynamic Systems Development Method

FEM – Finite Element Method

GAS - Generative Assembly Structural Analysis

GPS - Generative Part Structural Analysis

GUI – Graphical User Interface

LCA – Life Cycle Assessment

MBD – Model Based Definition

PPM – Product Planning Meeting

PQ – Product Portfolio Meeting

R&D – Research & Development

RT – Truck Chassis Development Department at Scania

TA – Test Assignment

YD – Technical Product Planning & Vehicle Validation at Scania

YR – Research Office at Scania

1. Introduction

This chapter presents the thesis; background, purpose, delimitations and research questions. The background gives a general view of how product development and software usage is rapidly changing all over the world. Besides, important definitions and processes are explained within an introduction of Scania as a company. After that, problem analysis is stated, followed by the purpose, the established research questions, and delimitations. As a closing of the chapter, an outline of the Master Thesis is displayed with brief explanations to provide an overview.

1.1 Background

Several trends can be seen within the industry today. Two of them, globalization and digitalization, are factors that have a large impact on the way of working. The increase in globalization is a game changer of speeding up the development, influencing the shortening of the timeframe. The timeline for product development has been reduced at a high pace in the last years and the trend shows that it does not slow down. Other affecting elements are the competition against companies, fast development of technical software and the change in customers' demands. (Krause, 2007)

Strategic companies must implement new ways of working to keep up with the changes that are occurring within the industry. Two areas that continuously keeps developing and rapidly changing are innovation management and simulations. As seen in the report from the early nineties, written by Bjärnemo, Burman & Anker (1993), the need for integrating the two areas has been explored for a longer period. However, modern aspects of innovation management push new changes and the need for further investigation of the integration.

1.2 Innovation Management and Simulations

The two areas of innovation management and simulations must be limited and concretized to get a better understanding of the aim of this thesis. The focus segment of innovation management is the new working methodologies that are trending within the development of product concepts. The area of product concept development can be explained by the procedure of how new and improved products can be developed (Trott, 2017). Three trends that have gained momentum during the last years will be focused upon: Design Thinking, Double Diamond and Agile Methodologies such as the Design Sprint. The area of Lean will be briefly presented as well and compared to the Agile Methodologies. The four areas are chosen to be interesting since they all started to become popular within product concept development in the 21st century and are somewhat modern. Design Thinking as a term has existed since the 90s but companies started to gain interest in the methodology at the beginning of the 21st century and the methodology of Double Diamond was introduced in 2005 by the British Design Council. (Brown & Kätz, 2009 and British Design Council, 2016). The roots of Agile Methodologies go back in the history, as early as in 1960, however, the methodologies first started to be applied in 2001 with the creation of the Agile Manifesto (Sunner, 2016). These three areas of the methodology are influencing the industry and are modern trends. A more detailed explanation of each area can be read further down in the report.

The term simulation is widely used and the definition, retrieved from Oxford Dictionaries is:

Imitation of a situation or a process.

With the given definition, simulations remain an area that covers a range of processes. There exist many definitions of what simulations are, Virtual Nation (2014) describes it to create and re-create the reality in an environment where the users can control it. In other words, simulations are used to visualise the functionality of the reality under predetermined definitions. To confirm the definition from Virtual Nation (2014), Shephard, Beall, O'Bara & Webster (2003) state that simulations' primary meaning is evaluation and verification of the design. Concerning simulations, the area of technical simulations is chosen as the focus area based on a definition from the focus company. This categorization, a short description, and some examples can be seen in Table 1.1.

Table 1.1 Areas of simulations for Scania (Johansson, 2018)

Area of simulation	***Descriptive explanation and some examples***
Design	Modelling based software such as CAD software, Performance & Topology Optimization
Embedded	Software connected to mechatronics and electronics
Geometrical	Manufacturing software tools, CAM, Interference and Tolerances, Digital Built and Services
Technical	Engineering analysis software, CAE, Finite Element Method (FEM), CFD, Acoustics, Fatigue, Durability, Dynamics, Collision, Multi Body Simulation, Ergonomics

1.3 Scania as a Focus Company

Scania is a world-leading company producing heavy trucks, buses, and engines and offers a wide range of services connected to their products. The reach of their products and services is global, as of today, Scania is present in more than 100 countries. This global employer has around 49.000 employees, making it one of the top ten largest companies in Sweden 2018 (Lindsten, 2018). Scania is owned by the TRATON Group, consisting of Scania, MAN, Volkswagen Caminhões e Ônibus and RIO. (Scania, 2019a)

To be able to stand the competition within the industry and keep the leading position, Scania is forced to work actively with concept development and finding new innovative solutions. By building a culture that promotes innovation, the company is maintaining and securing an environment that is developing innovative solutions. (Scania, 2019b) One of the main innovations that Scania is known for is their unique modular system thinking which creates flexibility. Modularity has impregnated the history and continues to be a large part of their business. (Scania, 2019b) Several goals have been formulated to keep up with future changes, one of them concerns simulation-based product development, where a desire for implementing more simulation is one part. (Johansson, 2019)

Scania has a set strategy within the R&D department to align the processes towards the same goal. A brief overview of the strategy can be seen in Figure 1.1. To the left in the picture, the global trends that are affecting the company are presented, one of them being digitalization, which reinforces the aim of this Master Thesis.

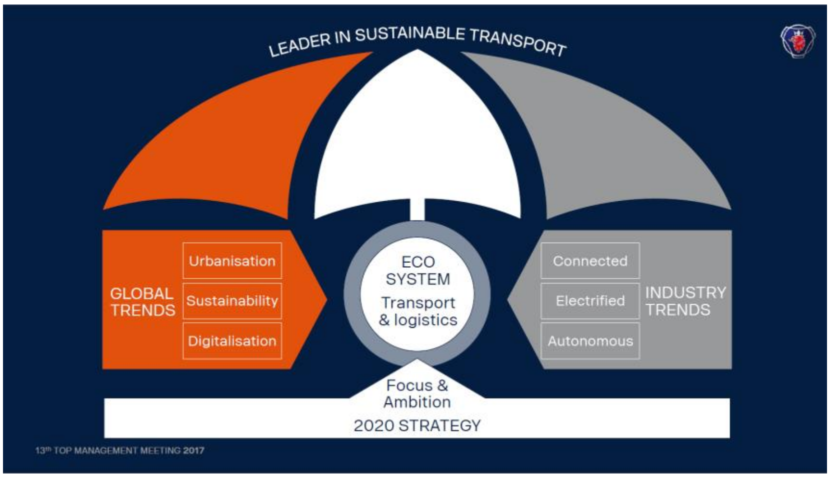


Figure 1.1 Scania's strategy (Johansson, 2018)

As Scania is a large company, the need for a good structure and organisation is significant. The organisation structure of Scania can be seen in Figure 1.2, with a focus on Research & Development (R&D).

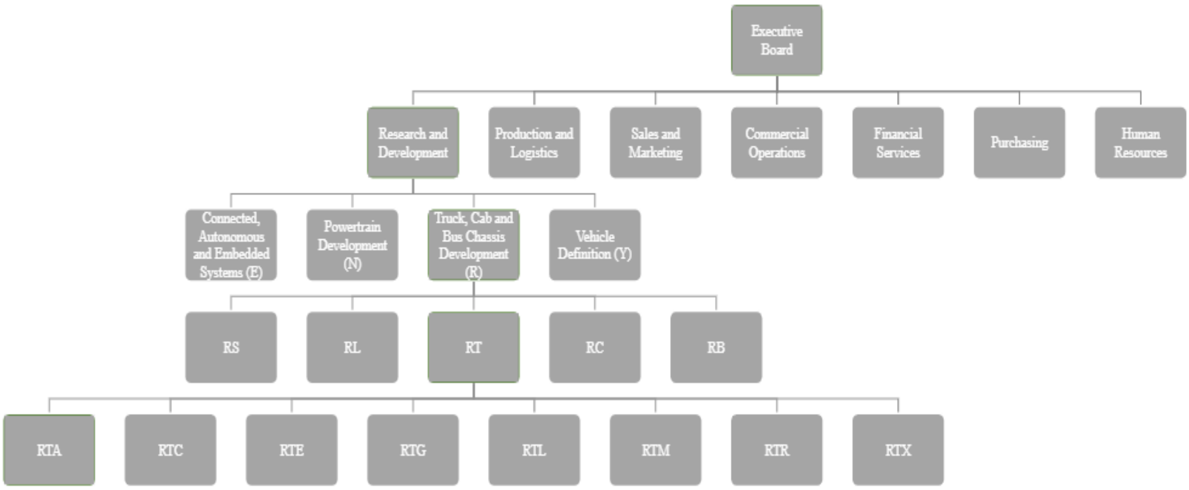


Figure 1.2 The organisational structure of Scania with focus on R&D (Karlsson & Vesterlund, 2018)

To gain a better understanding of terms related to Scania within this Master Thesis, a brief explanation will be made. The fifth level, signified by three letters, consists of the sections, controlled by section managers. Each section manager oversees several groups, led by group managers. The group manager's right hand is the object leader, who oversees the projects performed at the group. The groups are then often divided into smaller teams, led by a team leader.

As this Master Thesis will be looking into the area of product concept development related to modern working methods and technical simulations, concept development methodology at Scania needs to be further presented. Scania has developed a chart called Scania's Product Development Process, seen in Figure 1.3.

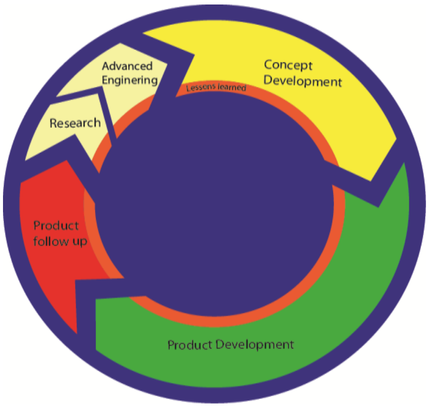


Figure 1.3 The different process types within Research and Development at Scania (Johansson, 2018)

The different stages of the product development process have varied focus. The first introduced is Research & Advanced Engineering, where new technologies are investigated and applied to Scania's products to improve the properties. The yellow process type, or the yellow arrow, is the pre-development process type where the concept generation and evaluation take place, exploratory actions happen, and the innovation perspective is in focus. The yellow arrow is the one that this Master Thesis will be limited to when gathering results and will be further explained in an own segment of the thesis. The green process type, also known as the industrialisation process type, follows, focusing on product development. The product is launched, and the red process type takes over, with product follow-up. (Johansson, 2019)

Even though the process types, in theory, are clearly separated, the yellow and green process types are placed within the same departments at Scania. This overlap helps to improve the exchange in knowledge, get better coordination within the projects and to simplify working iteratively. However, the undefined line between yellow and green arrow will lead to a challenge defining the system boundary of the concept development process type when performing assessment.

1.4 Problem Analysis

With the shortening of the development timeframe, there is a need to have a strategic approach towards modern product concept development and how to implement technical simulations within the company. There is a need to create prerequisites for, and encourage, modern working methods supported by technical simulations, to potentially improve exploration. There is nevertheless a lack of knowledge and there is limited academic research concerning the effects of the combination of modern working methods and technical simulations. It is a non-proven area and along with that, there is limited information about how it works within companies. There is a lack of knowledge of factors and components that can encourage or obstruct the use of modern working methods together with technical simulations. A brief overview of the problem analysis can be seen in Figure 1.4.

Figure 1.4 Formulated problem analysis of the Master Thesis

The focus company shows interest in implementing modern working methods as well as using technical simulations as a resource tool. Initiatives have been taken within the areas, such as working more Agile and implementing the sprint methodology, both presented further down in the report, but the department of RT struggles with low implementation rate. Concrete suggestions concerning activities of change to implement modern working methods and technical simulations need to be investigated. The reason for not conducting a study directly with these groups is that the focus company was interested in an objective input and not in being steered in a specific direction. During the process of writing the Master Thesis it however also showed that there is a lack of knowledge within each department, section and group concerning what changes other departments might conduct. This individualistic approach is highly dependent on the fact that Scania is a large and complex company, making communication difficult.

1.5 Purpose & Research Questions

This Master Thesis aims to suggest activities of change concerning the applied methodology within product concept development, the yellow arrow, and to create prerequisites for, and encourage, modern working methods supported by technical simulations, to potentially improve exploration. With the help from this study, Scania can hopefully promote innovation and the use of the relevant technology in an early stage of concept development at their R&D department. Before suggesting any methodology activities of change for Scania, a foundation of understanding must be created. This basic understanding is created by investigating modern product concept development methodologies and technical simulations in theory from academia. The first research question is formulated:

R1 - How can a symbiosis between technical simulations and a modern way of working be implemented in explorative product concept development?

To answer this question a literature study is needed. The centre of interest is to see how scientific ideas and trends are describing the use of technical simulations and a modern way of working in the concept stage within product development. The advantages will be explored and the potential difficulties of implementing increased use of technical simulations will be presented.

The second step is to gain a deeper understanding concerning the current situation of product concept development at Scania, both the steering process as well as the actual implementation within the department. The second research question is formulated:

R2 – How are technical simulations utilised in concept development and what incentives affect the usage of technical simulations in the early stages of modern product concept development?

The first part of this question is to analyse how available simulations are used and where they are applied in the product concept development at Scania today, as well as other companies, both in theory through written processes and steering documents, and in practice during innovation work. In addition to the first part of the question, it is also of interest to see what challenges that can appear with the use of technical simulations. The second part of the question is to investigate what important factors that are necessary to implement to encourage the use of simulations in concept development.

To fulfil the aim of the Master Thesis of suggesting activities of change, the third and last research question is formulated:

R3 - What activities of change must be implemented to encourage modern explorative product concept development and simplify the use of technical simulations?

The answer to this question lies in the results from the research question R1 and R2. The focus of the question is to investigate the possibility to implement activities of changes in modern concept development and technical simulations to improve the strategic innovation management at Scania. Analyse of areas where simulations can be implemented will be done to investigate potential future strategic placements.

1.6 Delimitations

The research study will be limited to the Truck Chassis R&D department, at Scania, called RT. RT is divided into several sub-departments, one of them being RTA, the department's steering committee, which requested this Master Thesis. To get a better understanding of the area of which the scope of this thesis is limited to, it has been green marked in Figure 1.5.

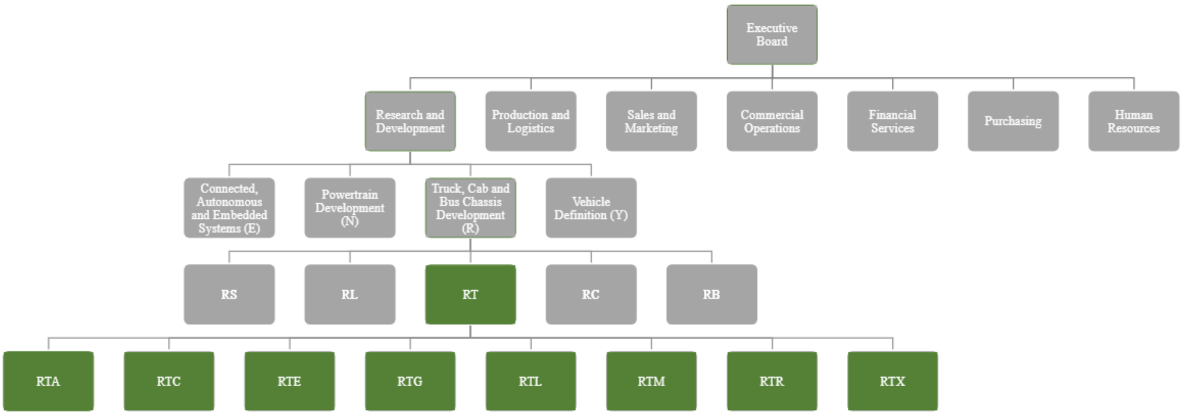


Figure 1.5 The organisational structure of Scania (Karlsson & Vesterlund, 2018)

Persons involved in the interviews will be restricted to responsible persons at RT, experts within technical simulations, simulation engineers, design engineers and persons directly linked to the yellow process type, concept development, at Scania.

The activities of change will be suggested related to the current processes of RT. However, to get an understanding of how it works at Scania in other departments, limited external data collection will be done at other groups. To include external departments is to increase the understanding and to gain knowledge and inspiration in the development of new working processes. External input will also be included in the form of a benchmarking study.

The Master Thesis includes two different areas, innovation management, and simulations, as previously mentioned. Concerning innovation management, modern working methods within product concept development is chosen as the focus area. Previously stated definition of product concept development will be used and the products that are in focus are the ones developed at the department of RT. The applied working methods are related to the yellow process type, or yellow arrow, in the R&D process, seen in Figure 1.3. The modern aspect includes a selection of dimensions such as Agile, Lean, Design Thinking and Double Diamond.

The simulation area that will be focused on in the thesis is the technical simulations and not design, embedded and geometrical simulations, see Table 1.1, and the focus will be on a generic level. This choice is restricted by the given task, due to time limitations and the interest from the authors, currently studying product development, and to narrow down the subject. The focus of the technical simulations is how it can serve as a resource tool concerning the modern working methods within product concept development and how and where it should be implemented.

To summarize, the delimitations of this Master Thesis will serve as a guideline to answer how methodology prerequisites and encouragement are created for modern working methods supported by technical simulations, to potentially improve exploration.

1.7 Outline of the Thesis

To get a good overview and understanding of what will be included in this Master Thesis, an outline is presented in Table 1.2. To simplify navigation between the different areas, a summary of each main heading can be seen.

Table 1.2 Outline of the Master Thesis

Chapter	*Heading*	*Summary*
1.	Introduction	Starting with a short background of the subject, presenting a problem analysis, purpose and research questions and ending with the thesis delimitations
2.	Methodology	Presents the research approach called a case study, data collection method and data analysis. In addition, a segment on research quality will be included, containing validity, reliability, research significance and source criticism
3.	Results from Literature Review	Included here are a literature study on innovation management and technical simulations and the interaction between the two areas with the aim to answer research question R1
4.	Results from Case Study	Presented here are the result from the case study with document study, interviews and observations, with the aim to answer R2
5.	Results from Benchmarking	Included here is the results from the performed benchmarking concerning product concept development and technical simulations, with the aim of answer R2
6.	Discussion	The result from previous section will be discussed and analysed, sources of error and potential improvements will also be illustrated with the aim to answer R3
7.	Conclusion	Answers to research questions will be presented and a final summary of the thesis
8.	Further Studies	Interesting aspects for further studies, both within the subject and neighbouring subjects, will be presented

2. Methodology

This chapter treats the theory of the used methodology for the study and how it has been applied. The first part of the chapter narrates the planning of the work, continued with the research approach by a literature review, a case study as well as benchmarking, followed by a description of the data collection for the case study. Afterwards, the method for data analysis for the case study is described to get a result from all the collected information. The chapter is closed after an evaluation of the research quality of the study.

2.1 Planning of the Work

To succeed in writing this Master Thesis, thorough planning has been made. Included are the different process steps, the planned duration as well as internal deadlines to be able to meet the final goal. With this working approach, the authors make sure that the content of the report fulfils the standards and reflects what the supervisors and the course requires. The set plan, as well as the outcome of the work distribution, for the twenty weeks, are presented in Appendix A. The workload has been distributed equally between the two authors, with Linnea Härder contributing with extra knowledge regarding technical simulations and Ebba Blomberg Cedergren with knowledge regarding product concept development. The focus has been on working as a team, making decisions together and sharing responsibility.

2.2 Research Approach

Presented in literature are several approaches to research methodology, both quantitative and qualitative. As seen in the book by Dagnino & Cinici (2016), the type of method that is preferably used in strategic management is a qualitative approach and more specifically a technique called multiple case study. According to Yin (2018), a case study can be applied when the study seeks to explain and provide an exhaustive description of a phenomenon. The case study can be considered optimal when the study is limited to a small number of people or a small geographical area. The given description can be applied to the previously stated research question number two, R2. To increase the generalizability and support answering R2, a minor benchmarking will be made.

To support the case study, a literature review has been made. The review will be answering research question R1, to give an extra dimension and further understanding when analysing and discussing the subject. The review will also support and reinforce the conclusion and show potential further studies.

Research question R3 will be answered based on the analysis of previous questions' answers. To get a better overview of the methodology and how each research question will be answered, a brief chart is created and presented in Figure 2.1.

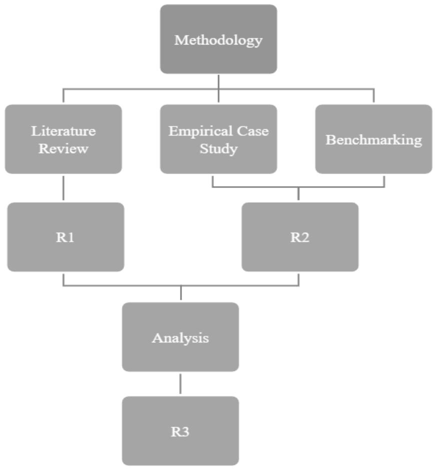


Figure 2.1 Simplified chart of Methodology

Within the Master Thesis there exist many dimensions and it was of importance to keep them separated, therefore was it needed to apply different methods to the different research questions to be able to answer them.

Alongside with the previously mentioned dimensions of collecting information and data, the authors have been located at Scania for twenty weeks, interacting with different co-workers for discussions and input. A group of co-workers, presented in Table 2.1, formed a steering committee, put together to provide guidance and feedback.

Table 2.1 Steering committee at Scania

Name	***Description***
Brantefors, Ola	Head of geometry chassis components, group manager for a design team
Muhrbeck, Ingela	Head of strength, acoustics and flow dynamics, group manager for a simulation team
Petrén, Olov	Manager over modularisation and the concept development process
Thellner, Mikael	Technical Manager, works strategic and supports the R&D organisation
Wieselblad, Anton	Innovation Coach, supporting exploration within system and software development

2.2.1 Case Study

Case studies can be divided into five iterative steps; design, prepare, collect, analyse, and share. The design and preparation of the case study will be made before collecting the data to set the direction and the goal. (Yin, 2018)

The design framework of the case study is presented in detail in the previous section; the introduction, where research questions, delimitations, and the purpose are presented. In addition, included within the design framework is the definition of the case study. There are three different main areas of a case study, exploratory, descriptive and explanatory studies. The exploratory case study aims to research a phenomenon or situation while the descriptive case study focuses on depicting. The explanatory tackling focuses on disambiguating the situation. (Yin, 2018) However, presented in other literature are other ways of approaching the research questions. According to McDonough & McDonough (1997), it also exists interpretive and evaluative case studies. In the evaluative case study, the researchers complement the case study by adding their judgement. Research question R2 will be answered by an exploratory case study, with the aim to explore a specific situation. Research question R3 can, on the other hand, be considered an evaluative case study. Concerning the preparation of the case study, those activities will be made when creating the interview foundation, before performing them. The collection and analysing of the data are presented thoroughly further down in the report. The last step is to share the information, which will be done with this report and final presentation for the concerned audience. (Yin, 2018)

According to Zainal (2007), the advantages of a case study is that it is easy to form a holistic understanding of the situation and to better understand the limitations of the study. Additionally, it helps to explain the system's complexity and interactions. The case study approach has also received criticism from several perspectives, for example, that it is a research form that requires large amounts of documentation and that it might be difficult to generalize.

2.2.2 Literature Review

As previously mentioned, a literature review will be performed with the purpose to complement, provide a gap analysis and answer research question R1. The review will be performed in several steps, making sure that it covers the main part of the subject. To simplify the research approach, the subject is divided into two areas. To perform a reliable review, guidance has been given by Damien Motte, Senior Lecturer at Lund University, Håkan Petersson, Lecturer at Halmstad University and Tobias Larsson, Professor at Blekinge Institute of Technology.

Several resources have been used when performing the literature review. The main source is the search portal from Lund University, LUBSearch, but Google Scholar has also been used as a supplement. To be able to retrieve the right amount of information from the suggested books, the resources have been lent at different libraries, such as the School of Economics and Management Library and the Faculty of Engineering Library at Lund University.

2.2.3 Benchmarking

A benchmarking has been made, to add a generalizing dimension to the case study and to give the result an external validity. The benchmarking was performed to investigate how other companies than Scania use their technical simulation processes; which simulations that are used, what they are used for and when they are applied. In addition to examining companies view on concept development.

To realize the benchmarking a thorough planning was performed. This planning was made on the basis that benchmarking is a method where information is shared to gain knowledge together, which makes it important that all participants are prepared for the benchmark and everyone is on the same side of the study (Karlöf, 2009). To collect the data for the benchmark, a simplified form was created. Due to a lack of time and resources, benchmarking interviews could not be made. The form was created by concretizing the content from the planning and the stated aim. The choice of companies to compare with Scania is selected based on two aspects. The first one is that the companies are in front of their industries, working actively with innovation. The other aspect is that the participants in the study have an interest in technical simulations and the usage of them. The companies of the benchmark are presented in Table 2.2.

Table 2.2 Companies included in benchmarking with a short description

Company	*Description*
Assa Abloy	Company that produces and sells door and door lock solutions (Assa Abloy, 2019)
Bombardier	Company that produces and sells products for mobility within the transport sector, such as trains and airplanes (Bombardier, 2019)
Haldex	Company that produces and sells brake adjusters for drum brakes and air disc brakes (Haldex, 2019)
Komatsu Forest	Company that produces and sells forest machinery as well as offering complete service (Komatsu Forest, 2019)
SAAB Aeronautics	Company that produces and sells military and civil aviation technology (SAAB Aeronautics, 2019)
Scania CV AB	Focus company that the other companies will be compared to
SKF	Company that produces and sells products such as bearings and units, seals, mechatronics, services and lubrication systems (SKF, 2019)

When all the companies had filled in the form and sent it back; the compilation of information was started. The analysis of the benchmarking consisted of defining and recognizing differences and find potential explanations. A large part of the analysis consisted of understanding the outcome of the collected data.

As the last step, two companies delivering software tools were participating in a smaller benchmarking survey. The smaller survey had the purpose to understand how software suppliers position themselves in the subject of the Master Thesis. The chosen companies to participate were Dassault Systèmes and Altair.

2.3 Data Collection for the Case Study

To collect data for the multiple case study, different empirical methods were performed. The choice of methods was made according to what the authors found important and where they would gain the most data from. Interviews, observations, and a document study have been made. Interviews were fundamental to get information about how the work is performed by employees. Observations were used to evaluate Scania's working environment and see the daily tasks. The document study was important to understand how Scania's written processes and steering documents provide guidance.

2.3.1 Interviews

Interviews constitute the major part of the collected empirical data. To be able to perform good qualitative interviews a thorough method needed to be written. Kvale and Brinkmann (2014) stated that it exists seven stages to design, perform and process an interview. Shown in Table 2.3 are the stages. It was decided to use Kvale and Brinkmann (2014) interview approach.

Table 2.3 The research interviews seven stages according to Kvale & Brinkmann (2014)

Project stages	*Content of the different stages*
Thematization	Formulation of the purpose and the idea of the study
Planning	Plan the arrangement of study in consideration of the seven stages
Interview	Performing interviews according to created interview guide
Printout	Preparation of the collected data to be ready for analysis
Analysis	Decision of what analysis method to be used appropriate for the made interviews
Verification	Determine the validity, reliability and the generalizability of the results from the interviews
Report	Report the result from the survey and the used methods to perform the interviews

It was decided to perform semi-structured interviews to collect empirical data. According to Lantz (2013), the use of semi-structured interviews should be applied when the interviews aim is to get the respondents experience and apprehension about earlier stated phenomenon and concepts. Another factor to make the interviews semi-structured was to have the same questions to all the interviewees but to let them talk openly and freely with their own words.

An interview guide was created before invitations to the respondents were sent out. An interview guide is written for the interviewer to structure the procedure of the interviews. When using the semi-structured type for the interview, the content of the guide consists of an overview of the subjects that will be brought up together with example questions. This is to be able to follow the respondents' answers and new directions that can open during the interviews. (Kvale and Brinkmann, 2014) The focus on the created questions was to make them open-ended hence to make the respondents talk with their own words, not limit their answers and to engage them in the topic (Yin, 2016).

When invitations to interviews were sent out it was together with a summary of what the authors are investigating, what will happen with the results, the pre-determined questions that will be asked and definitions of the keywords within the investigation. The expected time duration for the interview was given. In the invitations, it was also written about the confidentiality that exists when participating in the interviews and the option to cancel the interview both before and during the session. This thoroughly written information segment was sent out previously to the meeting to create the best requisites for both parts during the interview and to give the chance for the respondent to prepare themselves.

Documentation of the interviews consisted of taking notes on the computer and recording the interview from a mobile device. The notes from the computer were focused on the things that were not possible to hear from the recorded data such as body language, posture, and gestures (Kvale & Brinkmann, 2014). For all the interviews it was decided to have one author to ask the questions and lead the interview and the other author taking notes.

The interviews were decided to be done in two different rounds. The first round was a test round for the authors to evaluate the interview guide and to get a hint about the time duration. It was also a way to evaluate the author's performance and understanding of the subject. To perform one or two test interviews is to recognize your knowledge in the subject and to realize what you are looking for and why (Lantz, 2013). After the test round the interview guide was revised and the second interview round began. The second round of interviews consisted of the questions that the result will be based on. To keep high quality within the interviews the interviews were evaluated according to six criteria Kvale & Brinkmann (2014) have stated, see Table 2.4. If all criteria from Table 2.4 are fulfilled the performed interview has been ideal. It is difficult to obtain all the criteria; therefore, they can serve as guidelines of what the interviewer aims to accomplish. (Kvale & Brinkmann, 2014)

Table 2.4 Quality criteria for an interview (Kvale & Brinkmann, 2014)

Quality criteria
1. The width of spontaneous, rich, specific and relevant answers from the respondent
2. The width of short questions and longer answers
3. The extent in which the interviewer follows up and clarify the meaning in the relevant aspects of the answers
4. The interview interpreted mostly during the actual interview
5. The interviewer tries to verify their interpretation of the respondents answer during the interview
6. The interview "report itself"

The decision of whom to interview within each focus group was made in collaboration with the supervisor at Scania. The supervisor has been working at Scania for 35 years and can be considered to have good knowledge concerning the organisation as well as having an extensive network. Therefore, he had the knowledge concerning who could be of potential interest for the study. When performing the interviews, a snowball effected was created, where new potentially interesting names were mentioned.

It was decided to not have a given number of employees to interview, instead it was determined to interview the staff until fullness was reached. Hallin and Helin (2018) explain fullness as a state of mind when interviews have been performed and new interviews do not contribute to new information within the study.

Several interviews were performed to be able to answer the stated research questions. The main interviews that were performed were with a group of experts within technical simulations, design engineers and with the section managers at RT. To gain further understanding of how to work with product concept development within Scania could be performed, interviews were conducted with two interviewees at other departments than RT.

The interviews were held in Swedish, due it was respondents and authors mother tongue. Therefore, quotes from the interviews used in the report are translated into English as correct as possible to give the right meaning of it.

2.3.1.1 Research Ethical Principles

To perform a professional interview technique and to maintain an academic approach, the eight steps concerning good research approach from the Swedish Research Council (2017), seen in Table 2.5, will be followed.

Table 2.5 The eight steps from Swedish Research Council (2017)

	Description that should be followed
1.	You shall tell the truth about your research
2.	You shall consciously review and report the basic premises of your studies
3.	You shall openly account for your methods and results
4.	You shall openly account for your commercial interests and other associations
5.	You shall not make unauthorised use of the research results of others
6.	You shall keep your research organised, for example through documentation and filing
7.	You shall strive to conduct your research without doing harm to people, animals or the environment
8.	You shall be fair in your judgement of others' research

2.3.2 Observations

Observations made during the Master Thesis were both conscious and unconscious. The unconscious observations were made over a longer period since the authors wrote the thesis at the company. The conscious observations were planned and decided to be an open observation combined with an active type. Observations of the open type were used due to the aim of the thesis which was to see possibilities and improvements at Scania. Open observations can be explained as: that the researcher has informed the sources about the ongoing study and the researchers' intentions with the examinations (Ahrne & Svensson, 2015). There was no hidden agenda for the observations, which was another part using the open observations. It was important to let the informants know the authors meaning of the sightings. To use the active type of observation was decided because of the desired aim to observe the informants with the possibility to ask them about their work and let them explain. The decision whom to observe was taken by the authors and inputs were given from the steering group. The observations were carried out at the informants' workplace, where they could perform their daily work. The authors' way to document observations was as suggested by Ahrne & Svensson (2015): documentation of the things that the observer considers to be meaningful.

2.3.3 Document Study

Documents have been collected from Scania through their internal webpage "inline", and from the different sections of RT. The documents have also been received from local computer folders at Scania. The document study aimed to investigate the support existing from Scania within the chosen subject concerning how the concept development process should be handled. Documents that were interesting to study were steering documents, written processes, written methods, educational materials, reports, journals and written strategies of the yellow process. The documents were studied regarding the content but also in comparison with the results from the made interviews.

2.4 Data Analysis for Case Study

2.4.1 Interviews

The analysis of the material starts when the authors listen through the recorded material, meaning that a part of the analysis was made early during the study. The type of analysis which was carried out during the listening was connections between interviews and literature, interpretations as well as conclusions. (Hallin & Helin, 2018) To interpret the gathered information, an interview analysis with a focus on the meaning was performed according to Kvale & Brinkmann (2014). The method was chosen because of that the focus of the study was on what the respondents said and not how they said it. Therefore, the content was of significance. During the analysis, patterns were searched to be able to formulate results and conclusions.

Coding was used to process the gathered information from the interviews and helped to interpret the content. The meaning of coding is to connect one or more “keywords” to text segments to simplify the identification of stated data to the analysis. When using coding it exists two different types called concept or data-controlled coding. The difference between the two types is concept controlled coding have fully developed codes before the interviews start and data-controlled coding means that the coding is created during interviews and when the data analysis starts. (Kvale & Brinkmann, 2014) For this analysis of information, it was determined to use data-controlled coding, the choice was based on that there were no pre-developed codes adaptable to this study.

By using coding as an analysis method, it helped to sort out which problems were frequently told during the interviews. Due to the interviews were made independent from each other the mentioned problems strengthen the need for investigating and evaluating them. Hence, it is important when independent sources see the same problems. (Kvale & Brinkmann, 2014)

2.4.2 Observations

When observations were done the authors took time afterwards to translate their working notes to more summarizing notes. As mentioned in section 2.3.3 Interviews, the analysis of the collected data starts at this point. The analysis of the observations was inspired by the data analysis of the interviews, focusing on the content to answer the stated research questions.

2.4.3 Document Study

The analysis of the collected documents was performed according to content analysis. The content analysis focuses on the meaning and impact of the written words and sentences. (Ishiyama & Breuning, 2011). Qualitative case studies constitute this Master Thesis; therefore, a qualitative content analysis was performed according to (Ishiyama & Breuning, 2011). A comparison between the gathered documents and the collected data from the interviews were made in the purpose to see how the theory matches the reality.

2.5 Research Quality

There are two different terms to evaluate the quality of the stated research design according to Yin (2018); validity, consisting of construct, internal and external validity, and reliability. Due to that, the performed case study was considering to be exploratory and evaluative there has been no evaluation of the internal validity. This because internal validity is for explanatory and casual studies, the aim of it is to seek and establish a causal relationship. The meaning of a causal relationship is to know how and why certain conditions are believed to lead to other conditions. (Yin, 2018) To evaluate the quality of the Master Thesis, research significance, research moral principles and source criticism are also discussed further down.

2.5.1 Validity

The use of case studies is closely linked to social science and often used in that area. Therefore, to apply it in a technical research study, as in this Master Thesis, can be questioned. However, the purpose of the thesis is influenced by social aspects and how co-workers are using different technical tools. The thesis focuses on a strategic perspective with a qualitative approach that motivates the use of a case study and the validity concerning the content.

2.5.1.1 Construct Validity

The meaning of construct validity is to find and use correct methods for the studied questions within the research (Yin, 2018). To increase the construct validity, Yin (2018) suggests using multiple sources of evidence as a tactic. He also implies that it is important to establish a chain of evidence and to have a draft of the report reviewed by key informants. For this Master Thesis, the suggested tactics have been used. The use of multiple sources of evidence have been applied; documents, interviews, and observations are a part of the case study. A chain of evidence was maintained during the thesis. The reason is to be able to follow the gathered data from collection to final findings as well as the steps within. It is also necessary to be able to trace the findings from the data back to the collection. In other words, a chain of evidence is a derivation of how data is gathered in the design of the case study. (Yin, 2018) Drafts of the report have been reviewed by people within different fields of knowledge. Therefore, by conducting the proposed tactic, the Master Thesis is considered to have strong construct validity.

2.5.1.2 External Validity

To see if the results and findings from the performed case study can be generalized, external validity is of significance. External validity tests can be performed in different scenarios, it can be tested according to use theory in single-case studies or use replication logic in multiple-case studies. External validity is not only about showing if the case study findings are generalized but also how the findings can be generalized. (Yin, 2018) Due to the chosen research questions for this thesis, the generalization of the content is limited and therefore the external validity restricted. The result of the report is heavily influenced by Scania and co-workers. Interviews with employees at Scania will be affected due to the biased approach. To make the outcome of the findings more general, a literature review and a benchmarking study were performed, increasing the external validity.

2.5.2 Reliability

The meaning of reliability is to be able to get the same results by repeating the procedures for data collection (Yin, 2018). In other words, reliability is defined as if the study is repeatable or not. When performing a case study, it is uncommon to repeat the same study later again but Yin (2018) mentions the importance of still documenting the procedures as explicit as possible. Yin (2018) suggests two different tactics to evaluate and strengthen the reliability in a case study; either to use a study protocol or to develop a case study database. For this study, it was decided to use a study protocol to keep track of the different case studies. It was used for each case to follow the progress and how the planning of the cases proceeded, to strengthen the reliability. The use of a case study database is to organize and documenting all the collected data for the case study. The benefit of using a database is to have the gathered documents in order and to have easy access for the authors but also external persons of interest in the study. (Yin, 2018) Using a case study database increased the reliability of the Master Thesis.

2.5.3 Research Significance and Source Criticism

This Master Thesis will contribute to the general knowledge at Chassis Department, Scania, concerning methods within product concept development and technical simulations. With the generalization that follows with the benchmarking, other companies might also gain understanding around the area. To include software companies into the benchmarking the authors were aware of that the suppliers potentially being biased concerning the usage of technical simulations, the focus, however, was to understand how software suppliers position themselves in the subject of the Master Thesis, the symbiosis of technical simulations and modern working methods within product concept development.

Concerning the secondary sources used in this report, they have all been collected from similar search portals, which could give a homogenous result. The report could be further complemented with articles, journals, and books that are not represented as top search results within the different areas. The report is based on a limited number of sources, which could be further completed if more time is given. However, due to the limited time, the literature review has been performed as thoroughly as possible.

Concerning the used sources, some of them are old, published before 2000. All the used sources have been chosen wisely and the older sources have been even more wisely chosen, to not be considered outdated. Even if the subject of technical simulations is developing fast the older published sources are still relevant, the authors of the Master Thesis are conscious that not everything in the older sources is accurate with what is applied today. The outdated information is not included in the literature review.

3. Results from Literature Review

This segment presents the found theory within the research area. Starting with some stated definitions and explanations within each area, product concept development, and technical simulations, to gain further understanding. Concepts such as Design Thinking, Double Diamond and Agile Principles and Methods and Lean will be explained and linked to product concept development in relation to a modern way of working. The two areas of product concept development and technical simulations will then be integrated, investigated and benefits and difficulties will be presented.

3.1 Key Concepts and Evolvement of Product Concept Development

To be able to understand product concept development, some terms within product development need to be clarified. Innovation and invention are two words that are often used. It is therefore important to know the difference between them. Myers and Marquis (1969) stated a comprehensive definition of innovation:

> *Innovation is not a single action but a total process of interrelated subprocesses. It is not just the conception of a new idea, nor the invention of a new device, nor the development of a new market. The process is all these things acting in an integrated fashion.*

The stated definition of innovation can be considered old but is still used in contemporary literature such as Trott (2017) and will, therefore, be used as a definition in the study. The definition of an invention, which comes from Trott (2017), is cited as following and will be used in the Master Thesis:

> *The process of converting intellectual thoughts into tangible new artefact is an invention.*

Also, the terms exploitations and exploration are commonly used in product development. According to the Cambridge Dictionary, the denominations are defined as: exploitation, the use of something to get an advantage from it, and exploration, the activity of searching and finding out about something. In Figure 3.1 the two appellations connection is shown. The scope of the Master Thesis will lie at exploration in the study, but the denominations are strongly related.

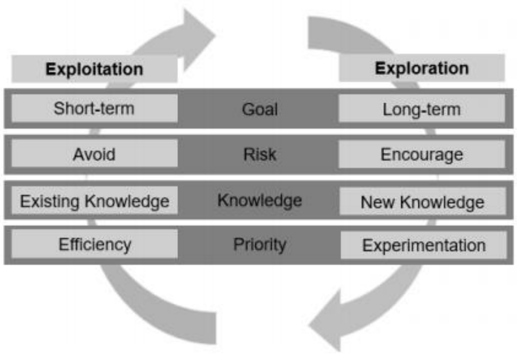


Figure 3.1 The relationship between Exploitation and Exploration (Karlsson & Vesterlund, 2018)

Product concept development focuses on the innovative and explorative part of product development, stated in the book by Andreasen, Hansen, and Cash (2015):

> *Conceptualization is the process of creating something previously unknown or unseen: a new product.*

Product concept development has evolved and, according to Keinonen and Takala (2006), the current innovation process seen today in the industry is the fourth generation. To understand the meaning of the fourth generation, a brief explanation of the previous generations is made. The first generation was based on technological capabilities, the process was driven by technology. The second generation was distinguished by the propulsion of the customers' demand and market driven activities. The aim during the second phase was to introduce new technical products influenced by the customer demands. The characteristic of the third generation was the importance of an organisation’s anticipatory external information. The meaning of the organization of the information was to predict trends and future technologies. To collect the information and have a good organization of it leads to the possibilities to build strong strategies for the innovation process. The fourth generation is influenced by the previous three generations. The focus of the latest generation is the importance of speed in the development process. It is also of significance that tasks are performed as early and accurate as possible. (Keinonen & Takala, 2006)

3.2 A Modern Approach to Product Concept Development Methodology

To be a successful and lucrative company, and to maintain responsiveness, it is important to have a good process for innovation in product development. It is crucial to support and develop the area of product development to increase creativity and to have solid ground for good evolvement. (Skarzynski, 2008) The significance of an innovative working environment and the rapid changes within the development have formed new ways of working. As previously mentioned, the shortening of the development timeframe is pushing for new management strategies and new technologies to keep up and stay competitive. (Dereli, 2015) One of the key success factors to keep up with Front End of Innovation is the responsiveness to rapid changes (Ahlgren & Landström, 2017).

Due to rapid changes, new ways of working are formed. This new approach to workflow differentiates from more traditional ways of working, such as rate-based flow. A common methodology that is connected to the traditional way of working is the waterfall model. It is a linear methodology that flows downstream in one direction, consisting of ignition, analysis, design, construction, testing, deployment and maintenance. (Benington, 1983) Differences that can be seen is that the traditional way of working is stricter, goal-focused and linear, while the modern approach is iterative, welcoming of discussions and rethinking, cross-functional and focuses on knowledge-building. A summary of the main differences can be seen in Table 3.1. It is, however, crucial not to state that one way of working would be preferable over the other, this thesis simply focuses on the modern dimensions.

Table 3.1 Main differences between traditional and modern way of working (Nerur & Balijepally, 2007)

	Traditional View of Design	*Emergent Metaphor of Design*
Design Process	Deliberate and formal, linear sequence of steps, separate formulation and implementation, rule-driven	Emergent, iterative and exploratory, knowing and action inseparable, beyond formal rules
Goal	Optimization	Adaptation, flexibility, responsiveness
Problem-solving approach	Selection of best means to accomplish a given end through well-planned, formalized activities	Learning through experimentation and introspection, constantly reframing the problem and its solution
View of the environment	Stable, predictable	Turbulent, difficult to predict
Type of learning	Single-loop/adaptive	Double-loop/generative
Key characteristics	- Control and direction - Avoids conflicts - Formalizes innovation - Manager is controller - Design precedes implementation	- Collaboration and communication: integrate weltanschauungs, or worldviews - Embraces conflicts and dialects - Encourages exploration and creativity and is opportunistic - Manager is facilitator - Design and implementation are inseparable and evolve iteratively
Rationality	Technical/functional	Substantial
Theoretical and /or philosophical roots	Logical positivism, scientific method	Action learning theory, Dewey's pragmatism, phenomenology

This modern way of working with product concept development, affected by globalization, digitalization, a shortening of the design timeframe and rapid development, has formed new methods of working with product concept development. The chosen areas that will be presented in this Master Thesis and linked to the modern way of working are Design Thinking, Double Diamond Methodology, Agile Principles, and Methods as well as Lean Production in relation to Agile. Therefore, when the expression "modern way of working" will be used in this thesis, it will be with the previously presented terms. As the modern ways of working focus on the iterative aspects of problem-solving and include different areas that need to be satisfied, there must exist resources that can reinforce, support and provide holistic understanding for this approach. A potential supportive tool could be the use of technical simulations.

3.2.1 Design Thinking

The term Design Thinking contains several interesting aspects and can be defined in several ways. One is that Design Thinking is an iterative and innovative approach to rapid problem solving, containing and combining analytical and creative aspects. People that experience Design Thinking for the first time might experience the approach as chaotic, open-ended and open-minded. (Ingle, 2018) To try to structure Design Thinking, five different stages are commonly used, presented and described in Table 3.2. (Dam & Siang, 2018) Even though the theory presents a linear way of working, the process is an iterative approach and the problem formulation can be redefined.

Table 3.2 Five stages of Design Thinking (Dam & Siang, 2018)

Stage	*Description*
Emphasize	This stage is about gaining understanding by observing and exploring the need of the user
Define	This stage is about analysing the gained knowledge and transforming the need into a defined and concrete problem formulation
Ideate	This stage is about generating ideas and exploring different solutions
Prototype	This stage is about building prototypes that could show potential errors and weaknesses
Test	The last step is about testing the built prototypes

The first step toward Design Thinking is to understand your business and its challenges. The challenges do not only include previous ones, but also new ones that might be faced ahead. When the foundation of understanding is laid, the next step is to clearly define the challenges and the reason why they need to be tackled. The third phase focuses on generating ideas and investigating potential solutions. The fourth step is to start prototyping and gain more knowledge about each solution to be able to make decisions concerning which solution to move forward with. The last step is to test the build prototypes, communicate the functions and physically explore the solution. (Ingle, 2013)

3.2.2 Double Diamond Methodology

The Double Diamond Methodology is an approach towards creating a framework for design development. The idea is to create a structured process for the creative procedure to provide guidance. A descriptive picture can be seen in Figure 3.2. It describes the different steps included in the creative process, both the convergent as well as divergent thinking. (Design Council, 2019)

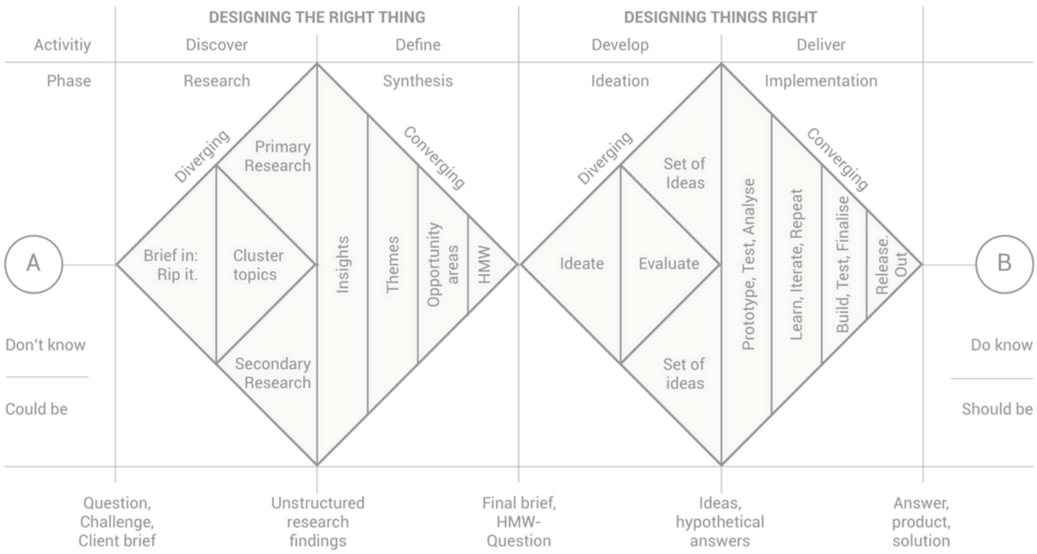


Figure 3.2 Double Diamond Methodology (Nessler, 2016)

The methodology contains of four different process steps: discover, define, develop and deliver. The first step focuses on gathering insights and researching the areas were the development will take place. The second step is the definition phase, a converging phase seen in Figure 3.2, where the possibilities from the first phase are sorted and analysed. The requirements are prioritized, and a design framework is created for further development. The third step is the development step, a divergent phase. Concepts are created and iterated, the idea is to focus on trial and error. The last and fourth step is the delivery step, where the idea is tested and analysed. Lessons are learned, and the product is being launched. (Design Council, 2019)

3.2.3 Agile Principles and Methods

Agile as a term originates from software development, where it started in 2001 with the construction of the Agile Manifesto (Beck et al., 2001):

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

However, there are suggestions on how the Agile Manifesto could be reworked, even though it has been criticised. A modification of the four pillars is presented by Denning (2011):

Team vision and discipline over individuals and interactions (over processes and tools)
Validated learning over working software (over comprehensive documentation)
Customer discovery over customer collaboration (over contract negotiation)
Initiating change over responding to changing (over following a plan)

Agile development differs from plan-driven development on several stages, for example focusing on making the working environment optimal for implementing changes. It is suitable to implement in small-scale projects with quickly changing requirements (Sunner, 2016). With an Agile approach, advantages have been registered, for example, the acceleration of the innovation process, risk elimination and the involvement of the entire organization. (Morris, Ma, Wu, 2014) Agile covers a wide range of dimensions, not all presented here in this report. Two of the concepts within Agile are Agile Methods and Agile Principles (Sunner, 2016), more closely described below.

3.2.3.1 Agile Principles

The Agile Principles are based on 12 principles that form a base for implementing innovations. (Hadley, 2017) The different principles, seen in Table 3.3 forms a somewhat structural approach to working Agile.

Table 3.3 12 Principles of Agile Concept (McKenna, 2016)

Principle	***Description***
1	Our highest priority is to satisfy the customer early and continuously deliver valuable software
2	Welcome changing requirements even late in development
3	Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale
4	Business people and developers must work together daily throughout the project
5	Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done
6	The most efficient and effective method of conveying information to and within a development team is face-to-face conversation
7	Working software is the primary measure of progress
8	Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely
9	Continuous attention to technical excellence and good design enhances agility
10	Simplicity—the art of maximizing the amount of work not done—is essential
11	The best architectures, requirements, and designs emerge from self-organizing teams
12	At regular intervals, the team reflects on how to become more effective, then tunes and adjusts

Closely linked to Agile Principles and Methods are the previously commonly used concept Concurrent Engineering (CE). The idea of CE implemented the first time in the 1980s, is that companies should work with cross-functional groups with a holistic perspective. The three foundational parts of CE are collaboration, process and information technology, which can all be seen in the Agile Principles. As well as Agile Principles and Methods, the CE faces challenges such as lack of in-house expertise, lack of communication and improper company culture. (Karningsiha, Anggrahinib & Syafi'i, 2015)

3.2.3.2 Agile Methods

Several methods and principles influenced the formatting of the Agile Manifesto. The mapping of the methods that contributed can be seen in Figure 3.3.

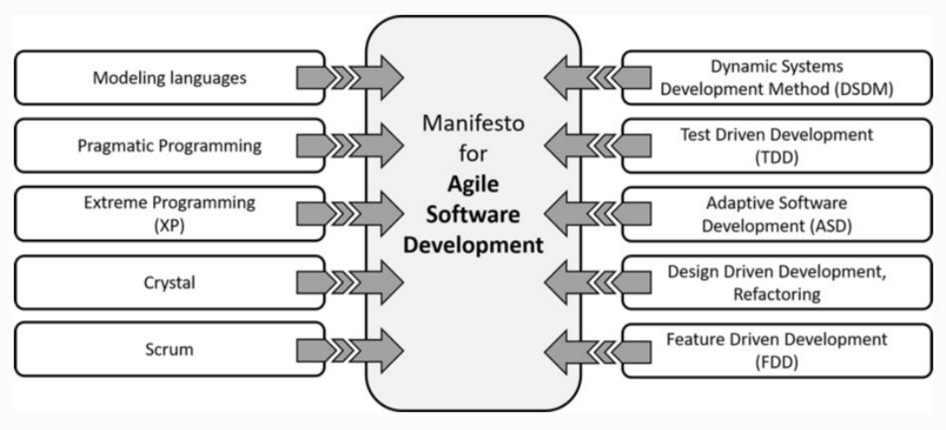


Figure 3.3 Methods that had an influence on the menifesto for Agile software development (Hohl et al., 2018)

Since the foundation of Agile development is within software development, not all methods are interesting concerning the aim of this thesis. However, two of them are more general methods, namely Scrum and Dynamic Systems Development Method (DSDM) and will, therefore, be further presented.

The Scrum methodology consists of three key players and three different stages. The first important person is the product owner, which oversees the gathering of requirements and specifications for the project, and this preparation is done in the first phase, the planning step. Here, the objectives are specified. The second phase consists of small incremental sprints, performed by the second key actor, the Scrum team. The team normally consists of between five and nine persons of different backgrounds with different knowledge. The group is led by the Scrum Master, in charge of controlling that the group is not disturbed by internal and external factors. This disturbance could, for example, be the product owner, which could change the objectives. Changing the goal or duration is not allowed during the sprint phase. The third and last step consists of closing the project with proper documentation and evaluation. A graphical illustration of the Scrum methodology can be seen in Figure 3.4. (Sunner, 2016 and Khalil & Kotaiah, 2017)

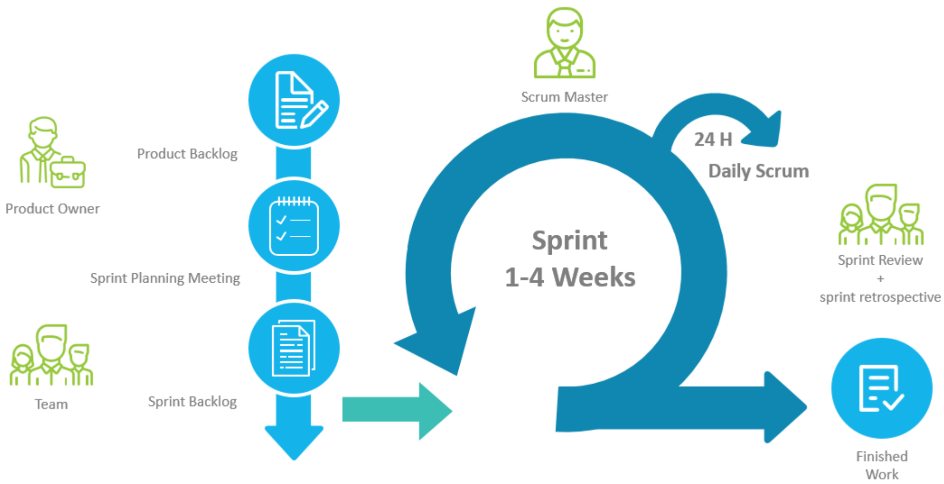


Figure 3.4 Visualisation of the Scrum methodology (PowerSlides, 2019)

Scrum methodology has several advantages for teams that can work concentrated on a project for a period. It increases productivity and efficiency, lower costs due to improved communication and increases quality since all team members understand potential problems. Another major advantage is that the Scrum methodology is scalable and could be applied to larger projects by using the scalability characteristics of the methodology, called Scrums of Scrums. It focuses on how the company can overcome the communication barrier between different projects working simultaneously by implementing so-called SoS meetings. (Srivastava, Bhardway & Saraswat, 2017)

Influenced by the SCRUM methodology is a method called Design Sprints. The origin of the method of the design sprint is the need of reducing the timeframe. The idea of the appellation is that difficult business cases can be solved within five days, in other words limiting the development time significantly. (Design Spring Academy, 2019) Before the five-day, preparation work must be done and when the sprint has started, each task takes just one day. The five tasks that should be completed during those five days are: understand, diverge, converge, build and test. Several advantages can be seen with the implementation of the Design Sprint. The usage will increase collaboration and understanding between different parts of the project group since the team is working tightly with problem-solving, forcing members to discuss, try their thoughts and talk. It provides transparency in the organizations and will highlight the potential knowledge gap within the project group. The use of Design Sprints could serve as a risk reduction tool. The preparation work that is being done breaks the project into smaller piece, increases the understanding of potential pitfalls and bottlenecks and could be helpful when calculating risk factors. (Banfield, 2019)

DSDM is a method that focuses on providing the exact solution at the right time and could serve as a complement to other Agile approaches such as Scrum. The focus lies in aligning projects and creating clear business goals to achieve good results. The method includes several principles, making it adaptable, scalable to a different project and works with a clear lifecycle perspective. (Sunner, 2016) The eight principles are: focus on the business need, deliver on time, collaborate, never compromise quality, build incrementally from firm foundations, develop iteratively, communicate continuously and clearly, and demonstrate control. DSDM has its base in several proven practices such as facilitated workshops, modelling, and iterative development, MoSCoW prioritisation and time boxing. (DSDM Consortium, 2019)

To be able to gain further understanding about what DSDM is, facilitated workshops, MoSCoW prioritisation and time boxing are explained. The facilitated workshop is formed when the company is growing, making the flow of information more difficult and complex. The workshops are highly interactive and let cross-functional co-workers come together at focus sessions. The sessions aim is to facilitate communication and exchange of ideas. (Project Management Knowledge, 2019) MoSCoW Prioritization is an Agile Methodology to gain knowledge about and help manage prioritises. There are four different categories: must have, should have, could have and won't have this time, to help the project group organize and highlight what needs to be handled. (Agile Business Consortium Limited, 2019) Time boxing is a way of being able to handle more tasks for one day. The idea is that your day is divided into time slots, or time boxes, where each task is set to take a certain amount of time. This division reduces the risk of spending too much time on just one task. (Mind Tools Content Team, 2019)

3.2.3.3 Agile Methodology and Double Diamond

Agile methodologies can be combined with other modern structured approaches towards the way of working. The Double Diamond framework, seen previously, can be put together with Agile Methodology. The four phases of the Double Diamond methodology; discover, define, develop and deliver, together with the Agile Methodology of identifying the problem and desired outcome and then iteratively develop a product can be seen in Figure 3.5. (Nessler, 2016)

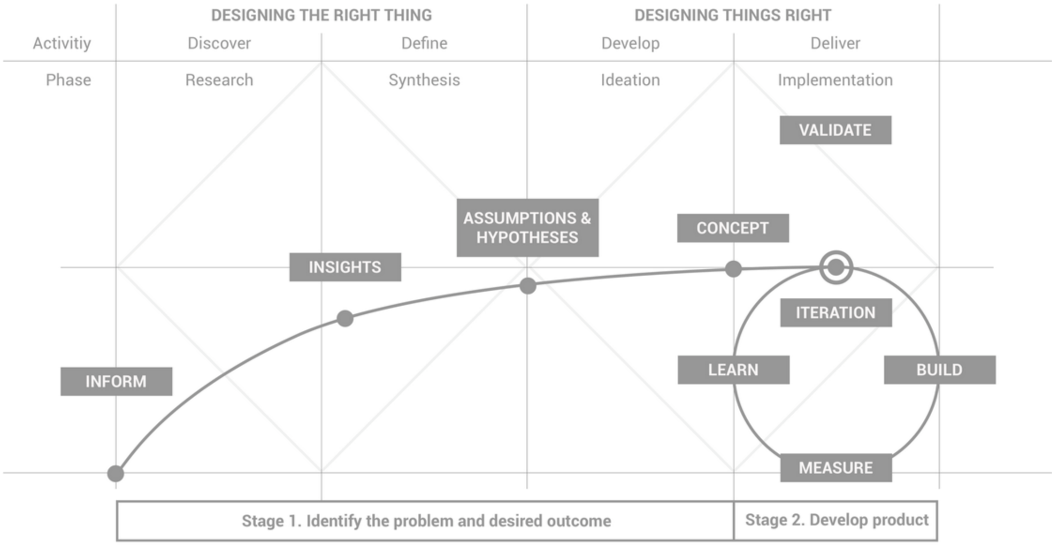


Figure 3.5 Double Diamond together with Agile Methodology (Nessler, 2016)

3.2.4 Lean Product Development

As previously mentioned, the focus of this Master Thesis will not be Lean methodologies, but as Agile and Lean are two areas, closely bound, a brief introduction to Lean will be done. The idea of Lean started in manufacturing, to deliver while continuously working with eliminating waste, both time and resources as well as reduce the time spent on doing tasks that did not add value. Each process step was assessed and investigate, whether it contributed to the value creation or not.

Lean philosophy has continued onto product development, where Lean thinking has been applied. The focus lies in the value creation and less in the waste reduction. Suggested by Pessõa & Trabasso (2017) are the five Lean principles, modified to fit the product development. The five principles are presented in Table 3.4. Lean is commonly implemented into product development, however, implementing it onto concept development could be difficult and complex.

Table 3.4 Five principles of Lean product development (Pessõa & Trabasso, 2017)

Principle	*Aim*	*Description*
1	Specify value	Understanding all the value requirements from the stakeholders for the whole product life cycle
2	Identify value stream	The product development process must be simple and contain optimized informational flows to prevent waste
3	Guarantee flow	During the product development the focus should be on single-piece flow, reducing value flow obstacles
4	Pull the value	Performing the process with pull events instead of pushing scheduled activities, highlighting quality problems and building knowledge
5	Seek perfection	Continuous improvement dives the lean philosophy and is performed by systematically documentations

3.2.5 Comparison of Agile and Lean

The Agile Principles and Lean principles can be compared and analysed together even though they might seem contradictory from the start. Agile is focusing on being adaptive to change, having shorter planning and commitment cycles, and focusing on collaboration and interaction. Lean aims to have a system view of a value stream, identify ways to eliminate waste and limit work queues, limit work from piling up and incorporating the pull effect. With the description of the two areas, Agile and Lean, the Agile Methodologies are more suited to be applied in product concept development while Lean is well fitted to be applied to product development. Lean is therefore not further investigated in this Master Thesis since the idea is easier to be applied to streamlined processes and would require a substantial amount of work to be applied to explorative processes.

The two concepts could, however, be used in collaboration. When looking beyond the written principles, four concepts within Agile and Lean are similar: improve quality, amplify learning, continuously improve and empower people. Even though the scope of this thesis lies in the analysis of Agile, it is crucial to know the differences as well as the complementary effect they have to one another. (CA Technologies, 2019)

3.2.6 Exploration Methodology

Presented previously are examples of how modern working methods can be implemented in companies. What can also be seen in the literature is the increased need for applying explorative methodologies within product concept development. Creative employees are an important factor for a company to be able to be exploratory and innovative. Creativity is not something that just happens, it is about putting ideas together and finding new combinations and approaches with the different ideas that lead to innovations. There is a challenge to be creative because the way of thinking needs to be different from the usual thoughts. There is a slight difference between working analytical and rational in comparison with a creative way of working, which are all variants of how to work as an engineer. A result of working in several ways is that it can be difficult to shift between them. For an engineer, it is easy to come back to the rational way of working by thinking what is technically possible and reducing the potential of thinking innovative. The ability to work innovatively can be learned and creative behaviour can be affected by external factors. (Lund & Tingström, 2011)

3.3 Technical Simulations

The digitalization within the industry can be connected to the term Industry 4.0, where the performance of the computers is becoming a key role (Marr, 2018). As seen in several larger companies today, the use of computer aid in combination with operating company adaptability is a must to be able to keep up with the rapid development (Johansson, 2019). It is becoming more and more significant to be able to exchange ideas between different parts within the company (Goffin & Mitchell, 2017). To be competitive as a company, some solutions can be implemented to make sure that the wake of the different trends does not give a negative effect. The use of computer software such as Computer Aided Design (CAD) and computer simulations will help to visualise results and present potential solutions, as well as to adapt to global trends such as globalization and digitalization. (Johansson, 2019)

Simulations today exist in several different types of businesses, where the progress has developed differently depending on industry and the driving forces each industry has. There is an identified need to develop simulations to be competitive against competitors. The use of simulations gives the ability to understand situations, behaviour, qualities, and processes in a virtual world before it has been applied in reality. (Virtual Nation, 2014) To make the development of simulations possible there must be driving forces to encourage the progress of change. Driving forces for the development of simulations are sustainable development, circular economy, customer experience, time, innovation ability and consumer services. (Virtual Nation, 2014)

Simulations can be used in different steps of the development process. The usage of simulations within product concept development have been explored and researched, and the results are clear. By using simulations in this phase, it increases the company's competitiveness by several factors. Collaboration with an external and internal partner and product quality and safety are just some of them that can be mentioned. (Bergström & Björkvall, 2015) Other interesting aspects of the use of simulations are the environmental and economic aspects. As Lagaros (2018) writes in an article, the amount of material can be optimized and reduced, which can lead to the reduction of carbon emissions. The use and implementation of technical simulations could be challenging and lead to uncertainties. As seen in the article by Mullins & Sutherland (1998), three main uncertainties can occur for companies, one of them is the problem with translating technological advancement into actual usage and knowing the benefits of them, an area that this thesis aims to fulfil.

To be able to fully understand the area of technical simulations, other areas must first be explained. Starting with the concept demonstrators, where the idea is that both physical and digital/virtual can be created. Demonstrators can be described as descriptions of specific parts of developing products. The demonstrator is not the final product but to represent the vision of the definitive result (Hallberg, 2012). The physical demonstrator can be prototypes where testing is the main tool to investigate and explore different solutions and their performance. The digital/virtual demonstrators are created in different CAD tools, creating both two- and three-dimensional models. The development within CAD is rapid and the two who use the technology needs to be explained to fully understand its potential, Digital Mock-up (DMU) and Model Based Definition (MBD). The concept DMU will be explained to be able to move forward to different simulation tools such as Computer Aided Engineering (CAE) and Computer Aided Manufacturing (CAM). A descriptive picture can be seen in Figure 3.6.

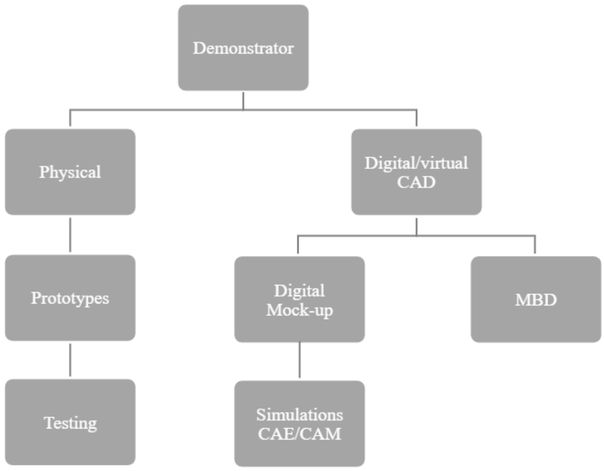


Figure 3.6 Strcutre of different demonstrators

3.3.1 Digital Mock-up

DMU is a three-dimensional model or digital demonstrator that serves as an assembly of different parts. The integration of different parts is included in the model as well as all the reference information. The DMU allows exploring interfaces, investigate the possibility to conduct maintenance and simulate system motion studies. With the complete model, information is easily distributed among different team members within the same project. Simulations can be applied to the DMU and then be referred to as an active digital DMU. (Siemens, 2019)

3.3.2 Model Based Definition

Moving forward in the development of digital demonstrators, MBD serves as a new trend. The idea of MBD is that the need for two-dimensional drawings can be removed by integration in the three-dimensional model of drawings annotations. The integration supports the benefits of having a single source of information and reducing the risks of creating conflicts between different inputs. A descriptive picture can be seen in Figure 3.7. (Quintana, Rivest, Pellerin, Venne & Kheddouci, 2010)

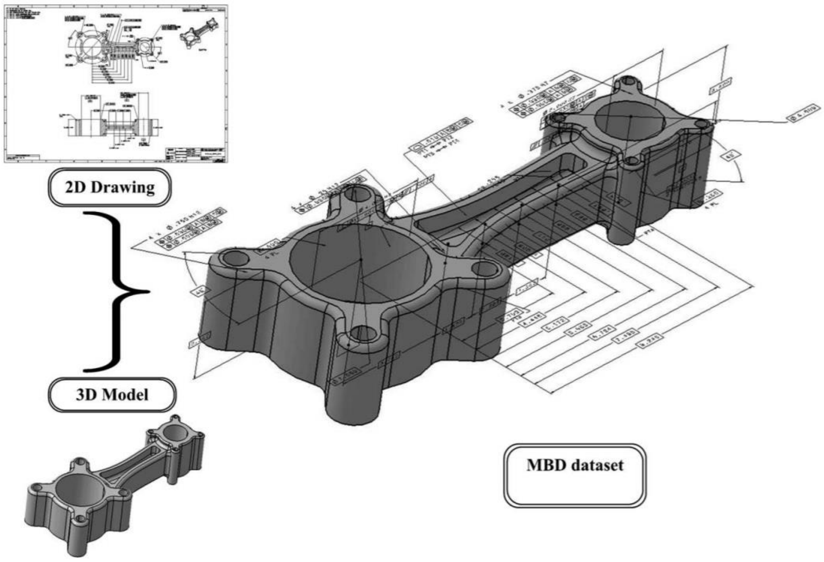


Figure 3.7 The fundament of MBD (Quintana et al., 2010)

MBD is a digital method that defines the manufacturing information for the product. All information that is required, such as a description of the needed tolerances and surface finish, is linked to the three-dimensional model. However, the method is not commonly used today within the industry even though this method reduces the need for two-dimensional drawings and allows including all the needed information directly in the three-dimensional model. The information that is stored within the three-dimensional model is Geometric Dimensioning and Tolerance, and Functional Tolerances and Annotations, making the model an information carrier. By using MBD the used number of documents can be reduced, and the need for manual labour can be decreased. The MBD model can also improve efficiency, minimize quality deficiency cost and reduce lead time. (Ruemler, Zimmerman, Hartman, Hedberg & Feeny, 2018)

MBD is a functional digital demonstrator and is a prerequisite for implementing automated processes in the product development process since the data is readable by a machine and gathered in the same model. However, there is a need for proper infrastructure and interfaces to perform automation. MBD is a step towards the digitalization of the industry and reduces the work tasks that do not create value. Several other advantages can be seen by different stakeholders. (Johansson, 2019)

3.3.3 Computer Aided Engineering

As previously mentioned, there are two main simulation areas, CAE and CAM. The purpose of CAM is to prepare designed parts from CAD for manufacturing with different digital machine tools. The use of CAE is to perform technical simulations as analyses of CAD geometries. (Shephard, Beall, O'Bara & Webster, 2003). To summarize it short: CAD geometry is the ground for the use of CAM and CAE.

Due to the fast development of software, there exists a wide variety of different technical simulations that can be implemented. The aim of the use of CAE and technical simulations is to virtually evaluate and verify if the design will function as expected under defined operating conditions. The result after simulations gives insight for the engineer and designer of how the part can be redesigned and improved. (Function Bay, 2014) Finite Element Analysis, Multi-Body Simulations, Computational Fluid Dynamics (CFD) and Optimization are just some examples of the technical simulations that exist.

Optimization aims to bring something closer to its ultimate state (Lagaros, 2018) and topology optimization is an important tool in simulation-driven product development, where it aims to change the layout within a given design space. By running topology optimization, it allows the software to develop the most effective shape according to the software algorithm in early conceptual stages. (Femto Engineering, 2019).

3.4 Advantages of Implementing Technical Simulations

By implementing technical simulations within a product concept development environment several advantages can be seen. When applying technical simulations early in the development phase, a front-loading will be created, having a spin-off effect on several beneficial aspects. This front-loading will give the chance of discovering potential problems, concerning, for example, solid mechanics, make changes and investigate the explorations of the design space earlier. (Thomke, 1998)

For the development of structural engineering, there is a potential revolution by integrating optimization software into the work. By implementing technical simulations, the opportunity for developing more advanced products will be a reality. There would be a significant improvement in transitioning innovations from laboratories and research department to the actual market. (Lagaros, 2018) The degree of innovation will be improved, which is confirmed by the Master Thesis from Bergström & Björkvall (2015).

Another effect of implementing technical simulations is that the use of CAE can reduce the number of prototypes made during development since CAE also supports the understanding of advanced systems. (King et al, 2003) By virtual models, the knowledge within the team will increase and bottlenecks and restrictions will clearly be shown earlier in the process.

These three effects, front-loading, degree of innovation and reduced number of prototypes, will lead to six main advantages. Three of the factors that could be improved are the quality and cost aspect of the product, as well as a reduction of lead times (King et al. 2003). With the new technology and fewer software restrictions, the ability to take all or several factors into consideration in design structures will also give an opportunity to have safer as well as eco-friendlier results. (Lagaros, 2018) Another crucial dimension that the technical simulations could give is the increase in knowledge awareness. (Krause, 2007) An additional positive effect of the use of technical simulations is that they could also serve as a complement to building prototypes with Additive Manufacturing (AM). The six advantages are summarized in Table 3.5.

Table 3.5 Advantages of implementing technical simulations

Advantage	*Description*
Quality aspect	Improved quality of the products
Cost aspect	Reduced cost for the development of new products
Reduced lead time	Shortening of the total lead time from idea to customer
Sustainability aspect	Opportunities to assess and explore environmental decisions
Knowledge awareness	Reduced risks with understanding concerning product choices, delimitations and trade-offs
Advancement in AM	Complementing the technical simulations and gives the opportunity to explore and communicate different solutions

Further ahead the mentioned advantages, quality and cost aspect, reduced lead time, sustainability aspect, the reduced risk, and advancement in AM will be discussed and presented with concrete examples.

3.4.1 Quality, Cost and Reduced Lead Time

The advantages, related to quality aspect, for the use of technical simulations, is the increased amount of time that can be added to improve product quality. With a front-loading approach, more time will be available to run more tests, making sure that the product will fulfil quality restrictions. (Thomke, 1998)

Besides the increase in the quality of the product, costs can also be reduced. As Shephard et al. (2004) and Lagaros (2018) states, that simulation-based design decreases the cost for the development of products and supports developing cost-efficient products. As previously mentioned, by implementing

CAE and simulations there is a reduction of physical prototypes. The production of physical prototypes is expensive, and by minimizing the production of such models, material costs can be saved. Costs can also be reduced due to the shortening of test cycle time. (King et al, 2003) As seen in the article by Roth (1999) a reduction of cost can be as much as 50 percent by applying technical simulations early in the product development phase. The reduction of costs and the increase in quality are significant to maintain profitability and competitiveness.

The front-loading in the development process, has, as previously seen, a positive impact of the shortening of development time. It is strengthened by Shephard et al. (2004) acquiesce with King et al. (2003) that products can be developed within shorter timeframes with the use of simulation-based design. This time-reduction shows that technical simulations will support the modern idea of the Design Sprint, where products are developed within a shorter amount of time.

If the time frame for the development could remain the same, the introduction of technical simulations could lead to that the number of iterations can increase, meaning that more design changes could be made. Changes in the design made on the computer are less time consuming than if changes needed to be done on a physical model. (King et al, 2003) The shortening of the development time frame will also lead to products reaching the market faster, which could induce gaining market share for companies and remain to be competitive (Roth, 1999).

To summarize: several advantages can be seen by using CAE and simulations in the early stages of product concept development and the final product and solution will have a higher quality in a shorter time with a lower cost in comparison with a traditional development method (King et al, 2003).

3.4.2 Sustainability Aspect

Technical simulations could act as a supporting tool for Life Cycle Assessment (LCA). Seen in an article by Schoggl, Baumgartner & Hofer (2017), there might be restrictions when applying LCA in the early stages of product design. This restriction is due to the lack of information and a high degree of uncertainty, area in which technical simulations can contribute to an overbridge. As previously mentioned, the use of technical simulations will provide information earlier and will help to make design choice, opening for the opportunity to apply LCA.

The use of today’s LCA analysis will, together with the simulations, contribute to making sustainable product choices. The simulations will be able to support LCA with information concerning, for example, weight and amount of material that is needed to produce the product. On the other hand, the results from the LCA will show what might need to be changed to achieve a more sustainable product. (Lagaros, 2018) However, it remains a challenge to use technical simulations as a tool for providing information for LCA since there is no life cycle perspective included while using simulations. Accessible tools to use within simulations do not include a long-time perspective. (Jaghbeer, Hallstedt, Larsson & Wall, 2017)

3.4.3 Knowledge Awareness Leading to Risk Reduction

An area that must be highlighted when discussing the advantages of early technical simulations implementations is the knowledge awareness that it creates. The use of simulations will help to explore the fullness of the design space, comparing different options, show delimitations and potential trade-offs that must be considered. The knowledge input will also stimulate co-worker’s courage to explore the creative design space. (Krause, 2007) It gives a greater understanding because of the possibilities to monitor system behaviours that are not possible during testing on physical prototypes and with the standard instrumentation. This monitoring increases the knowledge of the engineers and risks can be reduced. (King et al, 2003) As Zipperer & Amori (2011) states in their article, that knowledge management is a good way to support risk management.

The front-loading of the product development phase, pushing as early as concept development, will require investment. This initial cost might be a risk for the company and could potentially lead to a reduction in product quality. However, as Özaksel (2008), states in the report from Swerea, investing in cost-reduction processes, such as technical simulations, will not lead to lower product quality.

3.4.4 Advancement in Additive Manufacturing

AM is a modern technology which has developed fast the last couple of years and is done by printing CAD models in three-dimensional, in both thermoplastics and metals. Why the use of AM has increased is because it can be considered the best method for quickly manufacturing prototypes and the manufacturing cost will decrease. Another factor contributing to the use of AM is that the printed components are of the same strength and quality as components from traditional manufacturing methods. It is also considered to reduce the environmental impact of manufacturing. (Kianian, Tavassoli, Larsson & Diegel, 2016) The use of AM is a complementary method to technical simulations during product concept development. Technical simulations could serve as a first tool to explore and investigate potential solutions and then using AM to manufacture prototype components, the solutions can be visualized and communicated. It is important to adapt the selection of a method to the aim of communication and what needs to be explored. (Nicol, 2011)

3.5 Difficulties of Implementing Technical Simulations

Difficulties concerning technical simulations that are presented in literature can be connected to both the implementation as well as the usage. To begin with, presented by Zapf, Alber-Laukant & Rieg (2011) is the importance of connecting the theoretical knowledge around technical simulations with practical program applications. This connection could cause several problems, presented in Table 3.6.

Table 3.6 The recognized challenges concerning theoretical and practical work (Zapf, Alber-Laukant & Reig, 2011)

	Challenges
1.	No consideration of the user’s level of knowledge
2.	Information overflow, no situation specific support
3.	Lacking information on needed simulation data
4.	Missing guidelines and workflows
5.	Interface problems for data Exchange
6.	The absence of retrieval opportunities for formerly projects and search routines for analogies

CAE and simulations have a great impact on the product development but there are still key components that are missing to reach the fully developed potential that lies within CAE and simulations. (Shephard, Beallb, O’Barab & Webster, 2003) Besides the previously mentioned six difficulties, in Table 3.6, other difficulties are presented in the literature. The six previously difficulties have been reworked, together with complementing aspects to get a somewhat complete understanding of the difficulties. A summarizing overview of the difficulties found in the literature in Table 3.7. Following there are thorough explanations for each difficulty, presented together with concrete examples.

Table 3.7 Difficulties of implementing technical simulations

Phase were the difficulty could arise	***Difficulty***
Prior to implementation as well as during use	Knowledge for employees
Prior to implementation	Change of organizational structure
Prior to implementation	Scepticism from users
Prior to implementation	Problems with Implementing technical simulations early
During use	Mimic the reality
During use	Integration between software
During use	Restrictions in supplier availability

3.5.1 Knowledge for Employees

Knowledge around technical simulations can cause difficulties in the implementational phase as well as during the usage. Roth (1999) confirms the need for getting the proper education and knowledge of the simulations to be able to perform simulations of high quality. It is of significance to get an education before beginning to set correct input as well as interpret results and outputs. During the use phase of the simulations, the results need to be pedagogical and comprehensible for people that are not familiar with the work of simulations, since the results will serve as a base for further decision-making.

Difficulties that can occur when the knowledge and understanding are limited to a certain number of persons is that the group of experienced people are centralized and get all the requests of performing all the wanted simulations. By creating this limited group, causing a bottle-neck, the development time of the products might be longer. (Roth, 1999) Simulations are generally performed by analysts and there is, for the design engineers, a lack of knowledge concerning how the simulation tools should be handled. Communication problems between the different parts could cause problems when performing simulations. (Bjärnemo, Burman & Anker, 1993)

Another difficulty that might also exist when implementing new systems is the cooperativeness among experienced users. They could be critical to new, unconventional software that is different from what they already know. (Zapf et al, 2011) In other words are they not always willing to learn new software. Zapf et al. (2011) talk about the importance of providing help documents in all the areas of product development but the documentation of software technology is of significance. Failure within software systems is connected to inadequate documentation and non-intuitively usability.

3.5.2 Change of Organizational Structure

By implementing front loading into the development process, it means that the organization structure will change. The concept development has, before implementing front loading, been a small part of the whole product development process. With front loading, the time spent on concept development will increase. There must be a change of organization to fit the engineers, designers, and analysts in their new roles that are created to involve CAE. This change is preferably done by doing a transition with them so that they are involved in the project and can see the advantages that exist and can embrace the technology. (Roth, 1999)

There will also be a trade-off concerning which areas to implement the modern way of working together with technical simulations, and which areas that might still benefit from a more traditional flow-controlled way of working. This trade-off must be discussed prior to implementation.

3.5.3 Scepticism from Users

When presenting new technologies there is often a great scepticism with doubts regarding the use of the presented software. Lagaros (2018) states that it is up to the government and the scientific community to extinguish the scepticism and encourage curiosity and embrace new technology for the practitioners. The scientific community and the State need to force the implementation of new technologies. It can be made with clear explanations and examples of real-world applications to convince the users. Important to mention is that it is up to the practitioners to accept new design procedures to be able to make a change. (Lagaros, 2018) Scepticism among users could be based on resistance to change, the fear of having to do more tasks than before or doubting the outcome. To be able to change the opinion, it is needed to let the engineers go through a project with CAE to see the actual advantages.

3.5.4 Problems with Implementing Technical Simulations Early

Krotil & Reinhart (2016) states that there is a problem by using simulations in the concept development. They imply that it takes too much effort to convert the designed product geometry of a CAD file into a simulation model, because the model is changing heavily during the development of concepts. Because of this conversion, it would take a lot of time preparing the simulation and perform the simulation. Using simulations early can appear to be overwhelming for the people performing the simulations. Why it is overwhelming is because the concepts are often rough studies and the details are not determined yet which can make the setup for the simulation time-consuming.

To implement engineering analysis early in the design process it needs to be effective integration of the analysis into the process. To make it possible it is required to define the different simulation models with high fidelity early to have the ability to prepossess the design process. (Shephard et al. 2003)

3.5.5 Mimic the Reality

King et al. (2003) highlight a couple of limitations considering the integration of CAE analysis into the development process. It is difficult to mimic reality because of the complexity of the products and their physical performance. This difficulty appears because of the simulations are mathematical models which are based on approximations. The reality is more complex than the stated constraints and boundary conditions. The latest trend is to increase the calculating capacity, to be able to simulate the real world better with more accurate variation and distribution. (Virtual Nation, 2014) By creating better and more accurate approximations, the more complex the simulation will be, increasing the time and need for process power. The time it takes for the computer to prepare the model and perform simulations are critical because time costs money.

Even if the development of the software goes fast, the preparation and analysis time is still a big part of the simulations. It has been shown that the running time for the simulations is not decreasing that much. The preparation between translating CAD geometry to CAE geometry takes time, the meshing of the CAE model needs to be accurate and thorough and the setup of the boundary conditions and constraints need to be done to be ready to perform the analysis. (Roth, 1999)

To be able to rely on the results from simulations it is important to strengthen the quality of them. Therefore, is it important to create quality control within the software as well as a CE-marking. Another important aspect is to strengthen the reliability in simulations, which could be done by building a knowledge database based on performed simulations that can be applied when new decisions need to be taken. (Virtual Nation, 2014)

3.5.6 Integration Between Software

To use technical simulations properly, they are needed to be in collaboration with other types of simulations since they are the most efficient when complementing each other. They have their function and purpose within specific areas which are often not like other simulations. These specific features lead to that the result from one simulation does not give a complete picture for the analysis of the design. (Roth, 1999) In other words, it is a must to implement several simulations to get the most out of the use of the technical simulations and to effectively solve the entire problem. This collaboration between different software requires a functional interface and an easy way to integrate them. (Roth, 1999)

Shephard et al. (2003) elucidate that there are differences in geometrical models between CAD and CAE, the model description is different between the two systems. Because of that difference, it creates a longer lead time and more expenses within the development phase. It is also affecting the correlation between design and analysis.

3.5.7 Restrictions in Supplier Availability

The function of hardware and software suppliers is essential to have a functioning working environment with technical simulations. The suppliers oversee functionality for the different software and organize training sessions and functioning licenses. Activities that are affected within the company are; organization of the analysis departments and execution and planning of running the simulations. (Eriksson & Motte, 2013)

3.6 Technical Simulations within Modern Product Concept Development

Since the two areas of modern working methodologies and technical simulations have, up to this point, been investigated separately, there is a need for understanding the symbiosis. There are several dimensions to modern working methodologies, but what could be seen is that they all focus on working iteratively and knowledge-building, to create flexibility and a more efficient development process. The above-mentioned technical simulations that are available at the market today can be implemented in different areas within companies and there are several ways of working with creative strategy.

However, when looking into the symbioses of the two areas, little academic research was found. The implementation of modern working methods and creating prerequisites for using technical simulations are often done separately and only a few sources, targeting this problem, could be found. This limitation in academic research aggravated the writing of this thesis. What could be found presented in the literature are summarized below. This lack of resources, however, shows the relevance of this Master Thesis and the potential to contribute to a deeper understanding of the symbiosis.

3.6.1 The Usage of Technical Simulations within Product Concept Development

The usage of technical simulations within product concept development can be applied differently. King, Jones & Simner (2003) emphasizes the importance of a strategic implementation of CAE analysis to succeed in a smooth product development process. It is also of importance to integrate CAE analysis attentive and appropriate to get an outcome with validity.

To introduce front-loading with CAE into projects is a strategic approach and it aims to decrease the needed effort and work that would have to be done if a traditional working model were applied. Front-loading aims to decrease development time. An explanatory picture can be seen in Figure 3.8 of how the front-loading aims to compete with the traditional working model. (Roth, 1999)

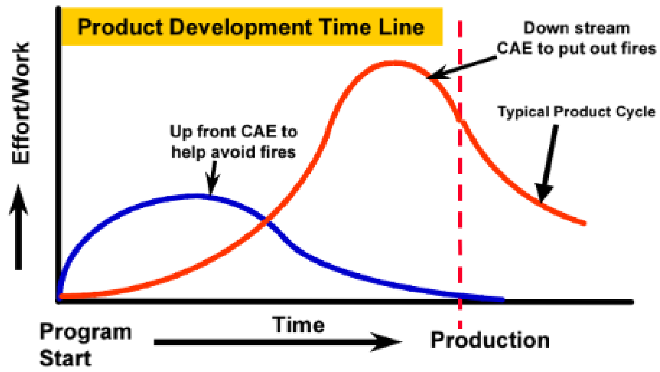


Figure 3.8 Demonstration of how early CAE can increase front-loading (Roth, 1999)

To apply CAE analysis early in a product development process, such as in the concept development process is crucial. King et al. (2003) state that it is easier to effect a change of the product in the early stages of development than later. It is important to be able to filter out bad concepts timeously. The use of simulations early should be obtainable because it can be most useful there, it gives the opportunity to recognize bad concepts, improve the design and to make changes and decisions early. The use of CAE early in the concept development process strengthens the inducement to use front-loading.

The usage of CAE in the early stages of product concept development, it can be used in an exploratory aspect instead of being used for validation. The use of technical simulation would promote the "What-if" way of working. The designer would have the opportunity to test, increasing their understanding and learn about the advantages and disadvantages of different solutions as well as potentially lowering the risk connected to decision-making. (Pocketsmith, 2019)

If changes can be applied early in product development it is preferable, due to the simplification of making changes within that phase. The longer the period that has passed, the more difficult it will be to implement changes. Given that technical simulations, CAE, are implemented early, and working with the resources iterative, the design process can be shortened. A demonstrative picture can be seen in Figure 3.9, explaining the implications of implementing CAE feedback loops early in comparison with a traditional waterfall methodology. (Roth, 1999)

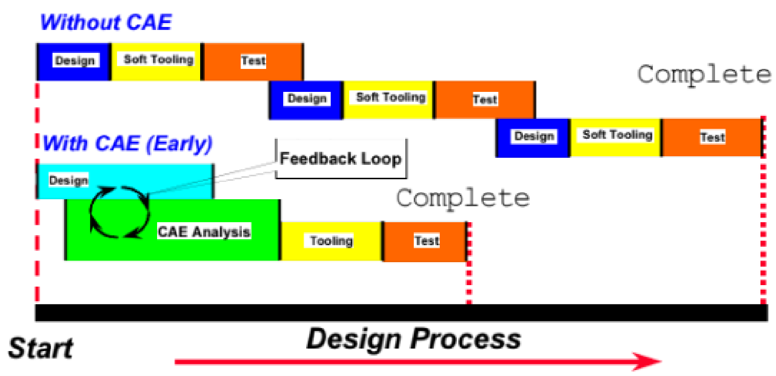


Figure 3.9 Demonstration of how feedback loops can ideantify problems early (Roth, 1999)

In an article by King et al. (2003), a good practice model for the implementation of CAE is presented. The implementation is built upon four pillars; product development process organization, hardware, software, and support & development. These pillars serve as guidelines to be able to implement and use CAE effectively. The product development process organization is enlightening that the understanding of the formal product development process is a must, thoroughly do the implementation, and implement CAE early in the product development process. Concerning the hardware and software pillars, they aim for creating both hardware and software that is built upon a system approach and support system optimization. Concerning the support & development, the company must create support structures, both on global as well as local level.

In the Master Thesis by Johnsson & Sätterman (2012) different automotive companies are compared regarding simulation driven development. One of the companies which were studied was SAAB Automobile and during the time for the Master Thesis and before, SAAB Automobile was strictly controlled to save money. The solution for SAAB Automobile was to introduce virtual methods according to CAE during their development processes instead of using physical tests and prototypes. The development decreased from six months to six weeks in the aspect of testing. The virtual simulations were driven in sprints with synchronization points for the design and simulation engineers and there was a close collaboration between the two engineer types. (Johnsson & Sätterman, 2012)

Traditionally it can be seen that the technical simulations are performed by a simulation engineer. What is becoming more and more relevant is that the design engineer is performing simplified simulations. Computer-Based Design Analysis (CBDA) is one kind of technical simulations with the purpose to support simplified analysis. The aim of using CBDA is evaluation, verification, validation as well as to support exploration in the aspect of evaluating design proposals. It is of importance to have an effective and efficient integration between design engineers and CBDA in development projects. (Petersson, 2016)

Petersson (2016) confirms what previous authors imply: the use of technical simulations in early development processes has several advantages. For example, the ability to take decisions early and to save time and money due to the reduced need of building physical prototypes. To implement CBDA in the concept development opens the possibilities to formulate concept variants with support from technical simulations. To create concepts with support from technical simulations it is needed that the design engineer has knowledge and understanding in both modelling and result interpretation from simulations. It is of significance to state that the simulations within CBDA have the aim of exploring ideas and in a short time be able to eliminate bad concepts. In the Ph.D. thesis written by Petersson (2016) some key recommendations are stated to be able to implement and promote the use of technical simulations by design engineers. In Table 3.8, the key proposals are presented.

Table 3.8 Key recommendations according to Petersson (2016) to promote the use of CBDA in concept development

	Key proposals
1.	Educate the engineering designer in design analysis
2.	Limit design analysis performed by engineering designers to well-formulated and delimited routine and basic design analysis tasks
3.	Do not reduce design analysis to an evaluation technique. Design analysis can be used for guidance, exploration and optimization and not only for the product to be
4.	Increase communication between the engineering designer and the analyst, especially during planning so that the “right” design analysis problem is solved
5.	Enhance coupling between design analysis, engineering designer and quality assurance
6.	Implementation of such integration is not straight forward and must be carefully managed
7.	Earlier design analysis allows for quicker verification
8.	Consider the enterprise configuration in which the design analysis activity takes place
9.	At the task level, emphasize the design analysis planning, which impacts the whole analysis early is also more efficient

3.6.2 Supporting the Modern Way of Working with Technical Simulation

As previously seen, rapid changes, globalization and a shortening of the development timeframe are forcing companies to apply new ways of thinking and a modern way of working to keep up and stay competitive. With the mentioned competitiveness among companies, it is needed to create a change in how products are engineered. To achieve this, it is important to reduce hardware prototyping and adopt a systematic approach to engineering. To promote Agile product development and an Agile working environment it is a must to use software development. (King et al. 2003) From a perspective of innovation is it important to be able to use and apply simulations to see and develop new possibilities and solutions (Virtual Nation, 2014).

The use of simulations has the chance of acting as supporting technology to previously mentioned keywords within a modern way of working. A summary of previously stated Double Diamond, Design Thinking and Agile Principles and Methods, and how technical simulations can support them, are presented in Table 3.9.

Table 3.9 How technical simulations could support a modern way of working

Aspect of modern way of working with concept development	*Support of technical simulations*
Design Sprint, Double Diamond, Design Thinking	Iterative
Agile principles and Methods	Continuously changing

The idea of Design Sprint, Double Diamond and Design Thinking is to create a process that is iterative and loops several times. The use of technical simulations will support that approach within the stage of ideate, making it easier to change parameters and to explore different solutions.

One of the Agile Principles is the continuously changing specifications, an area that technical simulations can contribute by having the chance to easily modify parameters and input data. Since Agile Methods are coming from the IT industry, it is difficult to implement in the manufacturing industry, where the traditional way, also known as stage-gate, is well-rooted. To be able to implement Agile Methods into the manufacturing industry a hybrid between the traditional way and Agile can be created, then called Agile-Stage-Gate Hybrid as one way to implement it. Why the producing companies wish and strive to implement agility is to be able to reach the benefits that the methods can contribute with. According to Cooper & Friis Sommer (2018), the traditional way of working is too linear and rigid. To effectively adapt to a fast-changing and unpredictable market that drives today's development of new products the traditional model is not well suited. An Agile method or a hybrid with Agile and traditional model is more suited to fit the changing market. The result of using an Agile model or a hybrid model with agility gives adaptable and flexible opportunities for change.

To apply Agile development into the product concept development process is to rapidly create working ideas and products with validity. The scope of the Agile way of working is development, testing and having a constant negotiation between new requirements and implementing them. A descriptive picture of this relationship can be seen in Figure 3.10. To promote the negotiation aspect, the technical simulation could support rapid changes. By applying a hybrid of an Agile and traditional model for the concept development process it allows developing a product visual. The visual product is created on the computer with appropriate software, which is made cheap and early and gives the possibility to get the product right quick. (Cooper, 2016)

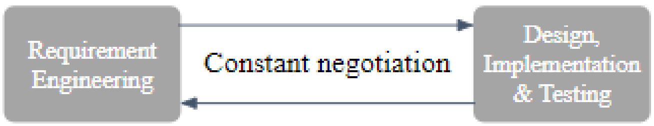


Figure 3.10 Agile development essence (Sunner, 2016)

With today's progress in technology, hardware development starts to become more like the development of software. Why there is a change in the hardware evolvement is because of that there are more electronics and electromechanical systems applied in the hardware products. This leads to the need to have the same development time, meaning that the process for developing hardware is becoming shorter and faster iterations are required. To be able to keep up with the fast iterations and development software has, hardware development must use new techniques and tools, such as technical simulations.

Because of the progress, development can be compressed, and implementation of multiple and short iterations are accessible. (Cooper, 2016)

When using sprints in an Agile model or an Agile hybrid model the use of simulations is a key component. Simulations are a way to reach the end of the sprint with a demonstrable, testable and integrational concept. (Cooper & Friis Sommer, 2018) For the whole product development process, including concept development, there are challenges in the form of new demands, higher efficiency and shorter lead time pushing companies to apply strategical changes. Examples of strategical changes that should be made are to apply new Agile development methodologies, supported by digital tools, such as technical simulations. (Geissbauer, Schrauf & Morr, 2019)

4. Results from Case Study

Presented within this segment are the results from the case study; the document study, the interviews, and the observations. The segment aims to answer research question R2. The document study will present the found support that is currently available to the co-workers at Scania. The interviews will further explain how technical simulations are used within concept development at Scania today. The final step is the observations, that serves as a supplement to previously done work, and gives deeper insight into the daily work at the focus company.

4.1 Document Study

The first step of the case study is to investigate published documents within Scania. This part will provide knowledge on what steering processes and available support that exist and what material each co-worker has access. The investigated material are within concept development, the yellow process, modern ways of working and technical simulations. The document study serves as a base to investigate available preconditions for each member of the staff, before starting the interviews and observations. To complement the document study and to map the current product concept development methodology at Scania, two interviews were performed with co-workers with expert knowledge concerning the concept development process in general and at RT. Presented in Table 4.1 are the interviewees.

Table 4.1 Interviewees in order by function and then name

Function	*Name*	*Description*
External informant	Petrén, Olov	Scania co-worker, YDMM – Manager
External informant	Jonas Wikström	Scania co-worker, RTLA – Project Leader

4.1.1 Mapping of Concept Development at Scania

At Scania today, the work with concept development is done within all the departments a Scania. The projects are often conducted as a collaboration between different parts of Scania, such as R&D, production and after-sales. The department called Technical Product Planning & Vehicle Validation (YD) is responsible to develop the yellow process type in an overall aspect. YD is also responsible for the modular system of main components, performance development of the trucks, technical market analysis, recommendations, legislative demand analysis and certificates. The organisation of YD consists of three sections, where one section handles technical product planning, one handles vehicle validation and the last one is responsible for regulations and standards. At YD over 160 employees are working, and within the technical product planning department, over 40 employees are working.

The purpose to evolve a general process is to be able to adapt the process for different departments. It is up to the departments that handle the project to develop the concept. In the following sections, the concept development process type at Scania is described, both in general and within RT.

4.1.1.1 Concept Development at Scania in General

To gain knowledge of how the general definition of the yellow process type is stated at Scania a document study was performed with a complementing interview with Petrén (2019a). Petrén narrated the Yellow Arrow process in general and explained the significant process steps and Decision Points (DP).

Before a project enters the yellow process, there are two process types coloured in light yellow which are called Research and Advanced Engineering. The responsible organisation of Research and Advanced Engineering is Research Office (YR). The purpose of the two process types is to investigate and develop new knowledge and technology in collaboration with universities, while the yellow process type is to focus on creating concepts. The green process type which comes after the concept development is called product development and focusing on industrialization, to introduce the product on the market. In documents the process types, yellow and green, are clearly separated but told from Petrén (2019) the process types are more floating, and the lines are diffuse between them. The scope of the thesis is product concept development so no further investigation of the product development will be made.

To recognize demands is the first step to start a concept development project. Demands can be identified in many areas at the company and from the surrounding environment. Ideas come from the customer, distributor, authorities, salespersons, product quality, service market, production, purchase, universities, and the R&D department. The demands can be improvements as well as exploratory ideas.

The line organization works with finding technical solutions and drives the project forward. Support can be retrieved from the YD department, the department which owns the yellow process. A concept development project manager is chosen within the department where the project is performed. As a project manager, you are, for example, responsible for leading and ensuring that the concept development project is delivering a result fulfilling the presented demand. The project manager also oversees the pace in the project, escalates deviations and promptly reports changes for the time plan. Other examples that are crucial tasks for the project manager are keeping track of spent resources and costs and answering questions from stakeholders regarding the project content and status. The yellow process type is handled by smaller groups, put together as a project group, to work on the specific task. The members are seniors and have previous knowledge within the area.

The construction of the yellow process type at Scania can be described as linear. The key parts of the process are Demand, Analysis of Demand, Configuration Concept Development, Concept Development, and Decision Preparation. To be able to drive the process from start to finish, DP is implemented along the way. Moving further into the next steps of the process there is a must that the DP approve the performed work. In every DP there is a presentation of the current produced work that has been done. The presentations are made for employees that have knowledge, experience and are affected by the project. Employees can question the presented work and give inputs. After discussion, a decision is taken, whether the project will go further to the next step, if the project will be closed or if it needs to be remodelled in the same step again. In Figure 4.1 the key parts and DP are presented in the concept development process at Scania. Shown in the same picture is also the transition from the yellow arrow to the green arrow, product development.

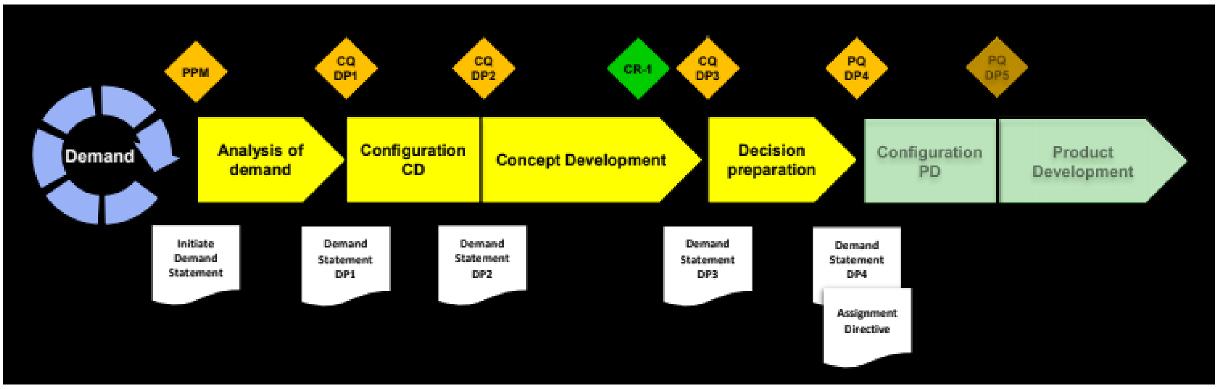


Figure 4.1 Key parts with the location of decision points in the concept devlopment process, as well as the shift to product development (Petrén, 2018)

4.1.1.1.1 The Different Decision Points and the Yellow Process Type

The yellow process type is initiated with Product Planning Meeting (PPM). The information that is needed to be collected before the PPM is held is: applications/product identity, properties/performance steps, customer demands, legal requirements, supplier chain, and components/services. The PPM is held when demand is identified and clearly described, the business case has been written with the benefits and costs for Scania, the customer are identified and the preparatory work according to the content of the meeting have been made. At the meeting, employees determine if the demand and the business case are described adequately. The participants of the meeting suggest potential employees to join the project group that are important for future steps in the process.

The next stage of the process is the Analysis of Demand. The identified demand is investigated, and proposals of solutions are presented as concepts. Within the concept product targets, the modularisation, potential business case, and proposal of configuration team are made, improved and examined. When Analysis of Demand has been investigated the DP1 and the first CQ are held. In the yellow process type process there are four DP, where the concepts are being assessed a decision is taken concerning whether the concepts are ready to move forward in the process. The core of DP1 is to brief the current state, request for money and resources. In this stage of the process, a stated demand must be clear, and a proposal of a concept have been made.

The next step of the process is Configuration Concept Development, the purpose of this step is to plan how the project will become Concept Ready. The configuration is performed by small teams working cross-functional. The team's main task is to define actions to generate and investigate concepts if there are no already existing concepts or if there are several concepts. If there is one concept the team's task is to create a risk list for the concept, where the list consists of risks which are needed to be eliminated to reach Concept Ready. Another task is that the teams have is to estimate the required resources and time which is needed to perform and complete the project. A milestone plan is created by the team to describe how the project will reach and fulfil Concept Ready. Important aspects of the planning are to eliminate high risk early and to schedule CR-1 as early as possible in the forthcoming step. DP2 and the second CQ decide if the actual concept development will start or if the project will be stopped. In other words, the second CQ evaluates the gathered information and evidence to decide if it is sufficient to continue to the next stage.

The concept development aims to fulfil Concept Ready and how each department do it is individual. The current definition of Concept Ready can be seen in Figure 4.2. The concept development projects at Scania today are most commonly 6 to 24 months. It is important to note that the length of the concept development process impinges of external factors. External actors can take a long time giving feedback or they could change visions or presumptions. At the end of the concept development process type CR-1 is held, to measure the matureness of the project and to assure that the concept is adequate. The review gives opportunities to improve the concept before the last CQ. DP3 is held when the development of the concept is ready, which means Concept Ready should be fulfilled. In the third meeting of Concept Portfolio decisions are taken regarding if the last step of the concept development process will start. DP3 includes a report of the previous work, where the project is right now and a request for funding.

Definition Concept Ready

Version 2017-04-04

❑ **Technical specification extract ready** [YDMP]

❑ **Bygglådeanalys**
Does the new performance step fit in the component series roadmap? [YDM]

❑ **Installation / Layout**
Concept secured in (digital) vehicles according to intended limitations in technical specification, volume/space needed and main interfaces secured. [RTMX/RBV/RCPL]

❑ **Preconditions for strength/durability estimated ok**
According to acceptance criteria in Design Guidelines

❑ **Hazard analysis, new technology and systems affected**
[CD team/ES]

❑ **HW, SW and/or system functional performance estimated ok**

❑ **Conceptual architectural design electrical system**
Concept or draft definition, depending on complexity, modularization secured [RESA]

❑ **Production concept defined**
Affected production process analyzed (e.g. SWOT, risk analysis). Input cross functionally communicated. Required process changes are identified. Digital- and/or physical test assembly/-packing made if concept critical. Make or buy analysis made if a new system is introduced. [M/KB/D]

❑ **Service concept defined**
Repair and maintenance concept evaluated (trouble shooting, ergonomics, tools, equipment and time) [YS]

❑ **Purchased components secured**
Availability of and sourcing strategy for concept critical components investigated. [S]

❑ **Support system requirement investigated**
New or changed support system (IT or process) identified [YM]

❑ **Legal requirement analysis performed** [YDR]

❑ **Patent intrusion investigated**
News scan performed and application registered if relevant [YM]

❑ **Business case**
Volume, markets (global/limited), customer benefit, price, profitability, window of opportunity and performance step. [KTP/KBP/KPP]

❑ **LCP ready**
Product pricing, cost & income change for customer with new concept [YDM]

❑ **NPV version 1**
Scania business, volume, Scania PD investment and dev. cost etc. [YDM]

❑ **Predicted targets for properties met**
Estimate of properties affected by introduction of concept – does the concept meet targets stated in Demand Statement, or during CD adjusted targets and expected benefits? [CR-1]

❑ **Remaining risks identified**
Identify which risks that are not eliminated during CD. (Risk list from configuration updated during CD) - can a PD project handle the risks that are left. [CR -1]

Figure 4.2 Scania's definition of Concept Ready (Petrén, 2018)

The meaning of having Concept Ready is to know when the concepts are finished and are ready to transit to green process type, product development. If Concept Ready is going to be considered complete the following targets must be treated: performance/properties fulfil recognized demand, the concept is possible to plan, the concept is cross functionally supported, the concept is developed according to modularisation and business case is investigated. The meaning of the investigated business case is to describe and clarify the expected benefits of the yellow process type project with Scania's business model.

The last step of the yellow process type is Decision Preparation, where an Assignment Directive (AD) is written. The content of the AD is the selected concept, recognized demands, remaining risk, and the stated business case. Time, cost, properties and profitability as project targets are needed to be stated in the AD. (Petrén, 2019b)

The yellow process type is finalized with the DP4 and Concept Ready evaluation. To host DP4, the remaining work should include risks that can be managed in a product development process, according to the project group (Petrén, 2019b). For the review, several employees are attending, those who would be affected by the concept if it transits to a green process type project.

4.1.1.2 Concept Development at RT

Since this Master Thesis is delimited to the department of RT at Scania, there is a need to further investigate how the process of product concept development is constructed at the specific department. An interview was conducted with Wikström (2019) to get a better understanding of the product concept development process at RT. The process created by the department of YD is a general description of what parts that are needed to be included in the procedure. However, each project differs from one and another, even within the department of RT. At the start, the core team is created, consisting of between five and nine members of different backgrounds and specialities. These members are chosen by the person in charge of the project. The resources are restricted before the concept has been assessed against Scania's business strategy, making the time limited since some of the team members are working with other projects in parallel. According to Wikström (2019), the length of the concept projects varies but a general estimation would be around 12 months.

The steering committee of RT has created a yellow processes chart adapted to the department of RT. Each of the process steps and involved areas within concept development is explained and exemplified, a descriptive picture can be seen in Figure 4.3.

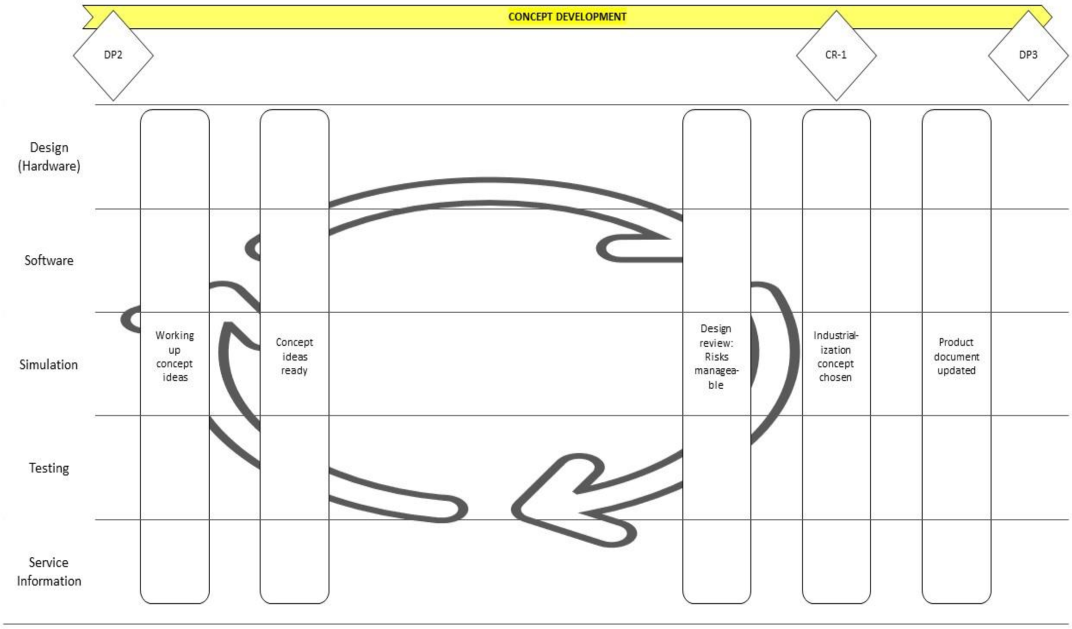


Figure 4.3 product concept development process at RT, Scania

Included in the concept development at RT are five areas, design of hardware, software, simulation, testing, and service information, as seen on the left-hand side of Figure 4.3. These different groups are working parallel during the concept development process type. The first two are connected to the design and the compilation of the new product. The simulation area includes the simulation groups and their software tools, and the choice of whom to include is conducted by the project leader. The testing group oversees analysing the physical prototypes that are constructed to improve and understand the developed concept. The last group is the service information, in charge of the handbooks for the vehicle, all documentation as well as driving education. The process of concept development at RT can be seen in Figure 4.3 to be both linear as well as an iterative process. Included are the three key DP, DP2, CR-1 and DP3 that was included in Scania's overall yellow arrow strategy, Figure 4.1.

When DP2 is passed, the concept development starts with working up ideas. If the concept already exists, for example from advanced engineering, supplier, competitor, there is not always a need for this step in the process. The next step is to have the concept ideas ready, followed by the design review and risk assessment. The three first steps are all part of the risk elimination loop, the risks identified as the most critical, defines what activities that are done in the loop and who must participate. The plan is done individually for each project, and risks that are not involved in the yellow process type would not be considered. When it can be considered that the remaining risks can be handled in the green arrow, the loop will be exited, the concept can be chosen and compared. The fourth step is the industrialization of the chosen concept where it is being assessed if the needs of the Demand Statement are being met regarding property impact, cost and investment, production impact, modularisation, and technical specifications. The concept must be technology secured and product properties defined. The final step is that the product documents are updated with for example risk analyses, ECO structures, requirements specifications, and GEO. ECO is an abbreviation for Engineering Change Order where all changes to the vehicle are structured and packaged together to get a better understanding and overview of the coming changes that need to be implemented. GEO is an organizational structure for the CAD software to be able to visualise different selected parts together.

4.1.2 Mapping of a Modern Way of Working at Scania

To continuously develop the processes of RT, an improvement work entitled “RISE of RT” has been created, where the Agile work at RT is presented. Three dimensions of Agile work at RT are presented: sprints, with product backlog and in autonomous teams. According to the document, being Agile means change-prone and flexible. The agile working method means that it must be easy to change the conditions and focus of the organization, to be able to quickly prioritize and concentrate on what gives the most value to the customer at the given time. Several Agile Methods are presented in the document, SCRUM is one of the mentioned. The goal of working more Agile at RT is to get more autonomous, change-oriented teams and groups, with increased efficiency and better well-being and working environment. (Thiel, 2019)

One of the mentioned examples of how Agile Methods can be implemented is through the planned sprints. The idea of the sprints can be seen in Figure 4.4. The sprint consists of four stages: sprint plan, sprint, design review and lessons learned. DF stands for design freeze, where all the geometrical models are stopped, and the current model is reviewed, no changes are allowed after the design freeze.

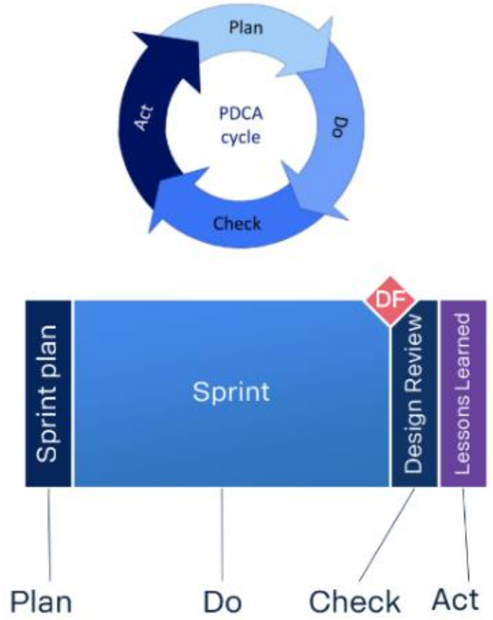


Figure 4.4 Planned sprint process with for stages (Thiel, 2019)

The planning phase set up prior to the sprint is a key factor for being able to perform the process. The SCRUM method has several given roles, as previously mentioned in the literature review, that needs to be filled with roles from Scania. During the sprint, a method for keeping track of how the project proceeds need to be chosen. A Product Backlog is a list of all features, functions, risks, deviations, and improvements that are relevant to the product in the current project. It is based on the product user's needs and a vision of how the need should be met. A backlog does not have to be complete from the start but can be developed together with the product. The backlog also includes an inbox containing new ideas, deviations, lessons, and wishes. These are lifted into the product backlog and get their place in priority order for next sprint planning. When the backlog is prioritized, one starts to perform the points at the top of the list. The scope of the sprint is determined by how many points from the backlog the group considers itself able to cope under the sprint.

“Rise of RT” was created at the beginning of 2019, but due to time restrictions and lack of resources, the methodology has not been implemented within the groups of RT yet.

4.1.3 Mapping of Technical Simulations at Scania

The area of technical simulations consists of several dimensions, just some presented here. Education for design engineers and simulation engineers varies and depends on which section the person is going to work in. The design engineers are given a training session in Catia, the CAD software, but the course in Catia GAS (Generative Assembly Structural Analysis), the simulation tool, is optional. Concerning the training for the simulation engineers, each person is given knowledge around the software used at the specific group.

There are general usage guidelines concerning technical simulations but there are no restrictions concerning the choice of software for the needed calculation. The decision concerning which software to use is done by each simulation group. However, there are guidelines about how the process should be performed when asked for a calculation from the simulation groups. A connection between the design engineer and the simulation engineer should be established and a Test Assignment (TA) sent, requesting the calculation. There are some guidelines concerning what needs to be included in a TA from some of the sections at RT, but there are no general guidelines at Scania. Examples of questions that could be asked when handing in a TA are: have similar simulations been made before, by Scania or externally? Do you know how many design iterations that might be needed? Are the models analysed in GAS? Is there a written GAS-report to be read? Is the issue solvable in GAS with support from Simulation? When the TA has been sent in, from the design engineer to the group manager for a simulation group, the calculation is performed, a review meeting held, and a report is written.

4.2 Interviews

4.2.1 Section Managers

Presented within this segment are the answers from the interviews with the section managers from RT and one external section manager, working at the department of cab development. The questions being asked can be seen in Appendix B. In Table 4.1 anonymisation of the interviewees are defined and the references in the following segment will be referred according to Table 4.2.

Table 4.2 Interviewees – Section Managers, department RT

Function	*Abbreviation*
Section Manager	SM 1
Section Manager	SM 2
Section Manager	SM 3
Section Manager	SM 4
Section Manager	SM 5
External Section Manager	ESM 1

4.2.1.1 Section Managers and Product Concept Development

The involvement of the Section Managers within yellow process type projects differ slightly and each manager focuses on different roles. For example, when SM 1 is being asked about the involvement, the manager states that the responsibility is by being involved in the source allocation and not actively control the project. According to SM 2, it is both being able to understand the inputs driving the concept development process as well as working with the right conditions for being able to conduct the process.

4.2.1.2 *Scania's Concept Development Process as of Today*

The interviewees are being asked about the current yellow process type and its challenges and difficulties. SM 4 describes the concept development process as it should be done in small groups during short time periods, preferably no more than five weeks. This short time period should be used to avoid getting a slow system. The process should be used to test different solutions and examine extremes. The line groups should be responsible for their subsystems and the development of them. Another grouping should be responsible for the overall system and taking responsibility for the integration.

4.2.1.2.1 Room for Improvement

SM 4 highlights some areas of improvement concerning the yellow process at Scania today. One example is that the department of YD is responsible for coordinating different properties and how the vehicle should look over time. YD should coach the line groups, but too much focus is spent on just developing components and the idea of the system is forgotten. SM 4 also means that there is a problem in the current concept development process since the concept is chosen too quickly, instead of keeping as many solutions ongoing as long as possible. The process of how Scania works with concept development differs but what is common is that the co-workers of Scania are skilled at continuous improvements of the different components and there is a lack of innovative solutions. The problem with a lack of explorative space is supported in other interviews with the section manager. According to SM 1, the yellow arrow has not produced any exploratory concept and since too much needs to be described before coming to CQ, people do not have the power to drive innovative projects. The manager says:

> *This organization is very good at implementing small changes to our little thing, to make the truck one-half percent better. We are not the best in the world at changing direction.*

The idea of the yellow process today at Scania is lacking an innovative part which is also highlighted from SM 5 and confirmed by SM 3. The yellow arrow has an entrance where the innovation has already been made, the idea has been found. The section manager states:

> *The yellow arrow that we have today, I believe that the entrance there is that we have already performed the innovation process. The innovation is finished before beginning the concept development.*

Another problem, mentioned by SM 3, is that Scania's major has been on finding the small improvements that could provide customer benefits. It has been sensible to wait and let the technology develop and mature and to fully understand customer needs. This way of working has been well-functioning when the cycle times have been long but as the world is moving faster new requirements appears. As SM 3 states:

> *We must find ways to listen to what is happening in the market and faster translate it into products.*

The needed time to perform a yellow process type project differs, most of the section managers cannot give a specific number. However, SM 4 does a rough estimation and guesses around 6-12 months, which the manager finds too long.

4.2.1.2.2 Defining Concept Ready

The idea of Concept Ready is interpreted differently between different section managers but the general thought is that it is somewhat simple to apply and use. According to SM 2, a concept is ready when:

> *Concept Ready for me, it is that we have taken the idea so far that we understand how it should be realized, the technical solution, what consequences the technical idea, or the new component or whatever it is, gets, partly for our full-vehicle characteristics, how it affects our production apparatus but also how it affects Scania's profitability.*

Concept Ready is, according to SM 3, a state where all technical risk is discontinued or well identified and when proceeding, no new risks should appear. According to ESM 1, the Concept Ready means that the project is plannable and ready for green process type: it is clearly stated who should be included, what it will cost, and how we should do it. The external section manager also states, in comparison to the section managers at RT, that the projects at Scania tend to move forward too quickly, with remaining risks. The external section manager also highlights the need for the concept to be visualised, either by software or hardware to make better decisions. This need of being able to visualise and communicate a concept is supported by several of the section managers. The idea of Concept Ready is, according to SM 5, you understand that one can achieve the characteristics in an industrialized way as well as understands roughly how to proceed to manufacture the component. One should also have a rough picture of what is needed in terms of simulation and testing.

4.2.1.3 Trends within Concept Development

There are several external factors and trends, mentioned in the interviews, that influence and push the development of the concept development process at Scania. As mentioned by SM 1, the products that are being developed are demand driven and is an output from the responsiveness within the company, and there is an increase in pace when it comes to keeping up with the customers. According to SM 4, hardware must be inspired by software development and increase the rate of development by implementing Agile working methods and sprints. ESM 1 also states that there are several trends within concept development, these could be for example streamlining, increased speed, being able to use simulation-driven development and avoid hardware. To summarize, speed is the trend mentioned most of the time in the interviews.

4.2.1.4 Changing to a Modern Way of Working Within Concept Development

According to SM 2, several aspects could be improved with the yellow process type at Scania today and there is a need for implementing changes since Scania is facing major challenges in electrification and autonomation. The changes, according to SM 2, would be to work more Agile, with sprints and time boxing. This due to an increase in uncertainties and changes in requirements along the project time. Working in shorter steps than today to be able to adapt more quickly and focus on building through the whole project, iteratively. Each time box, according to SM 2, should focus on solving a specific amount of problems with that block.

4.2.1.5 Technical Simulations within Concept Development

According to ESM 1, the simulations in yellow projects are used more intensive in periods and are not evenly distributed over time. The way of working with technical simulations is that the design engineers who oversee the roadmaps start the loop by sending a TA to a simulation group. Concerning the use of technical simulations in a yellow project, SM 3 thinks they are being used too badly. The calculation group is integrated too late since they are required to wait for a TA being sent. This way of working, according to SM 3, is leading to a backload of work. However, even though the design engineers have such a crucial role, there are more differences between individual design engineers than between the development process types at Scania (yellow, green and red) on how to choose and use technical simulations. The design engineers serve as a project leader, organising and controlling all the tasks connected to the development of their component.

According to SM 1, the design engineer sets all the properties against each other and balances them. The design engineer is placed in the middle and is acting as an administrative link between the different stakeholders. All stakeholders move in different directions and the design engineer must balance all different requirements while the only feature that the design engineer owns is the size of the detail.

4.2.1.6 Performing Technical Simulations

The person who performs the simulations differs, depending on which property that needs to be explored. Many simulations are specialized, but SM 1 clarifies that for example simple strength analysis could be performed by the design engineers. According to SM 3, there is a chosen division between design engineers and simulation engineers due to the need for having different knowledge, tools, and skills. As of today, as SM 3 highlights, the design engineer is working both strategic with roadmaps and operationally driving projects.

The division between simulation engineers and design engineers is problematic according to SM 4. SM 4 also states that the designer has far too much to do, especially of an administrative nature. Another example is that the geometrical model is changed when the simulation groups are approaching the simulation calculation due to a lack of communication. When being asked about the division of design engineers and simulation engineers, ESM 1 also highlights the problems connected to the coordination. The section manager would like to see a co-location of the two groups within short, intense periods. However, the division is required in the long run to be able to create specialised groups.

The relationship between the test engineers and the simulation engineers is highlighted by SM 5, who means that an experienced simulation engineer and test engineer can utilize each other's strengths. SM 5 also states the need for rearranging the structure of the design engineer, the simulation engineer, and the test engineer. SM 5 clarifies that the digital tools should be used first to understand the physics surrounding the product and testing for quantifying absolute numbers. This division is due to a matter of maturity in the simulation. One should not compare testing and simulation, as SM 5 states:

> *I do not think you should put testing against simulations, it is in a collaboration between those two where the profit lies.*

4.2.1.7 Factors Affecting the Usage of Technical Simulations in Concept Development

To increase the proportion of technical simulations, SM 1 implies that you must be able to see the profit in using the technical simulations and you must be able to answer the questions. SM 3 states that it requires a general understanding of all the competencies that are involved in computing groups and a proper invitation for the simulation groups into the yellow projects.

When being asked about factors that could encourage the use of technical simulations for the design engineers, SM 4 answers that it is difficult to control since the use of simulation software is completely individual dependent today at Scania. There are no regulations, so it will come down to if you are of analytical character, enjoying performing simulations or not. As of today, SM 4 states that there is a frequency problem for the tasks that the design engineer performs. The frequency problem is mentioned when interviewing ESM 1 as well, who states that there is a problem in maintaining skills. ESM 1 also says that the software needs to be user-friendly.

4.2.1.8 Supporting a Modern Concept Development with Technical Simulations

The use of technical simulations in relation to a modern concept development process is crucial and Scania needs to develop their process. As SM 1 states:

> *We must change the way we work with technical simulations because we need to work out better solutions in general, in a shorter time, for both yellow, green and red process types.*

SM 2 also highlights the need for technical simulations within modern concept development. Simulations should be applied before the development of the product has gone too far to early identify challenges and changes that need to be implemented. SM 3 highlights that technical simulations could support the need to increase speed since it takes time to wait for hardware and prototypes. The demand concerning speed from external will be a driving factor for the implementation of several technical simulations. This idea is supported by SM 4, who says it would lead to the ability to work and loop faster, supporting the idea of working iteratively.

4.2.2 Simulation Engineers

Within this segment, the content from the interviews with Technical Experts is presented. All respondents work in simulation groups where the colleagues mainly being simulation engineers, but a few test engineers appear in the groups. The interview guide which was created for the interviews can be seen in Appendix C. In Table 4.3 anonymisation of the interviewees are defined.

Table 4.3 Interviewees – Experts within technical simulations

Function according to the interviewees	***Name***	***Working within***
Group Manager	TE 1	NM
Group Manager	TE 2	RT
Group Manager	TE 3	RC
Group Manager	TE 4	NM
Technical Manager	TE 5	RT
Group Manager	TE 6	NM
Group Manager	TE 7	RT
Group Manager	TE 8	NT
Senior Engineer	TE 9	NT
Expert Engineer	TE 10	NT

4.2.2.1 Technical Expert and Product Concept Development

All the respondents have worked in a concept development project or been involved in those projects before the conducted interviews. The involvement differs between the interviewees. As a Group Manager for a simulation group, you are somehow always involved in the concept development process, according to TE 1. Working in a simulation group, the work is often of a great extent related to the concept development process. The involvement occurs when there is no possibility to perform physical testing and there is a desire to be able to realise faster loops. There is a great diversification of how the involvement is according to TE 3 and TE 4 depending on different concept development projects. Sometimes the involvement starts early in the yellow arrow and in other projects, the need for assistance comes late.

On the other hand, TE 6 explains that the expert's group is not especially involved in yellow process type projects now. TE 6 explains it is rare that the group participate in yellow projects early, sometimes they are assisting with simulations, but the contribution is rather small. If they participate, they are more of a support function to the design engineers, where they verify and compare different concepts with their developed calculation methods.

The relation TE 7 and its group has with the different process types at Scania today is that they work with all of them, but the group prefers to work in the concept development process. TE 7 says when there is an idea of a concept it is possible to perform the first technical simulation, to be able to evaluate if it has good properties. It is easier to enter a concept development project early if the project is performed close to the simulation group, explains TE 7.

Working as a group manager, according to TE 8, gives the possibility to work with the maturity of methods in the simulation group. Development of simulations methods gives the possibility to use them early in concept development and gives a strong faith in the result from the technical simulations. Well-developed methods will capture properties, explains TE 8.

4.2.2.1.1 Room for Improvement

According to TE 2, TE3, TE7 and TE 8, there is no need to change the concept development process at Scania. The process is described as “quite good” and it is clear with the milestones recognized as DP according to TE 2. However, some areas of improvement are mentioned, such as a miss of involving all the right people who would contribute with knowledge and different perspectives from the beginning in a yellow project. The consequence of not including the right people in the start-up of a concept development project is that specification of requirements is not complete, some demands are eluded. New specifications could appear later in the project and the outgrowth of missing demands generate retakes, which increase the cost and time according to TE 3.

According to TE 4, the concept development needs to change and states:

> *What I see now is that the concept development is quite controlled regarding that we already have decided what we will approximately do and when it should be introduced. The conceptual work, which is a continuous idea generating work and to take different concepts somewhere without thinking of when it will industrialise, have fallen away a little bit do I experience. […] Today we are not working with a spread of different concepts and funnel them down.*

There is always the potential for improvement according to TE 5, TE 9 and TE 10, in line with previously presented quote. Both TE 9 and TE 10 express the importance of more distinguishable definition in the concept development process, a clear definition of what the assignments and the objective are.

4.2.2.2 The Differences in Software from Group to Group

Depending on which department the interviewees came from the use of software differs. Both regarding different disciplines but also within the same disciplines different software was used for performing technical simulations. TE 8 explains that the use of varied software depends on the simulation group, but it is also depending on the simulation engineer. One of the reasons why there is a wide variety of software is regarding the background and experience of the simulation engineer, TE 8 narrates. TE 8 implies having several different software that can strengthen the use of simulations and offer flexibility but at the same time can it lead to losses in synergy effects.

4.2.2.3 Differences in Concept and Product Development Processes

All the interviewees' highlight that the current yellow process type is like the green process type regarding methodology as well as the use of technical simulations. As a simulation engineer, the use of the software does not change depending on which process type the project is in, in other words, the same software is being used in both the concept development and product development processes. TE 4 acknowledges the method of working is identical between the two processes but with different preconditions. The difference is assumptions need to be made in the concept development process but there are the same competence, employees and question formulations.

One difference, implied by TE 1, TE 2, and TE 3, is the amount of time spent on performing technical simulations. In the yellow process type, the technical simulations are more extended than in the green process type. It is explained by TE 1 that in the green process, the simulations are more distinct and in the yellow process, there is a greater need for understanding and knowledge-building.

4.2.2.4 Time Spent in Concept Development

According to all the respondents is it impossible to give a clear answer on how much time that is spent as a simulation group in the concept development process. Some of the interviewees were able to estimate the time spent in concept development and Table 4.4 present the time with main comments. It is also difficult to estimate how much time is spent on simulations in the concept development process type. This difficulty is affected by the fact that the simulations groups do not have any product owning and is therefore steered by the need and assignments from the assignment system called TA. The time spent with technical simulations in the concept development process depends on which activity the project lies within for the moment and how the project is disposed.

Table 4.4 Interviewees – Estimated time spent in concept development as a simulation group

Technical Expert	*Estimated Time*	*Comments*
TE 1	40 %	Difficult to determine how many people that are involved in the concept development project due to an employee divide their time between assigned projects
TE 2	20-50%	There is a great variation depending on which projects are active. Employees can spend 10 - 100% of their time in yellow arrow projects.
TE 3	30-40 %	The use of simulations is intensive in periods and are often performed early in the process

4.2.2.5 Assigning a Test Assignment

All the respondents answer the same on how an assignment to their group is created, there is no difference depending on which process type the projects are in. According to all the interviewees, the technical simulation is initiated and requested by a design engineer, for component, system as well as project. The first thing a job requestor should do is to have a conversation with someone in the simulation group, it could be the group manager, team leader or a simulation engineer. A conversation aims to get a first discussion about the assignment and to evaluate the idea of the intended simulation. After the first contact, the job requestor writes a TA (it is the same for simulations and testing) which is sent in and needs to be accepted before the work can begin. There are occasions where there is no first contact before a TA is sent in. When the TA is accepted there is a first start-up meeting held, where involved persons attend. During the first meeting, the demand is discussed together with what is needed to perform the required simulations, for example, input data, boundary conditions, geometries and for what cases simulations should be performed. Simulation engineers want to have a solid foundation from the beginning to have a smoother process and to save time. Start and end dates are set at the meeting.

At the simulation group, after the start-up meeting, the assignment is distributed to the simulation engineers after priority and set deadlines. After that, the work with performing the requested simulation begins. During the assignment work, there are follow up meetings where everyone meets again to discuss the performed and forthcoming work. When simulations have been performed there is a presentation of the results where conclusions regarding the assignment are presented and a discussion is held. Afterward, a report is written and archived. Later, a meeting called Lessons Learned is held, to evaluate the performed work and discuss the assignment.

For some of the interviewees' simulation groups, there are certain requirements before a TA is sent to the group, which are summarized in a checklist. Those lists are made to prevent doing extra work for the simulation engineer later in the project and to get a shorter take-off in the start-up of assignments. According to TE 2, there is no demand or checklist on geometries that are going to be simulated, which could be needed because there is a great variety between different design engineers performed work.

4.2.2.6 Design Engineer and Technical Simulations

All the respondents narrate that it exists technical simulation software connected to Catia V5 (the program for CAD used at Scania). The software is called Catia GAS and Catia GPS where GPS stands for Generative Part Structural Analysis. By using GAS and GPS, a design engineer can perform easier technical simulations with shorter solving time than if the simulations are done by the simulation groups. The different types of simulations that can be performed by GAS and GPS are cases related to solid mechanics and linear problems. The simulation performed are often quite simple and the purpose is to guide the design engineer in its design work. In addition to GAS and GPS, Catia V5 offers FLUENT which is a software that performs CFD simulations. A software called Altair Inspire which is a tool to perform topology optimization was also mentioned by the respondents to be a technical simulation software to use by the design engineer. MS Adams is a software that could be used for both the design and simulation engineers when working with multi-body simulations. The respondents can see advantages of using technical simulation as a design engineer, for example, the fact that the use is knowledge-building.

According to all the respondents it depends on the design engineer if they perform technical simulation by themselves, which in other words make it individually dependent. It was also stated that it was dependent on which groups the design engineer comes from and what interest hir has. Interest and knowledge are vital if a design engineer were to perform simulations.

TE 1 explains there is a frequency problem today with the usage of available technical simulations for a design engineer. The amount of time spent on performing simulations is too low. To build knowledge within the area it is a must to perform simulations with higher frequency. TE 1 adds to the reasoning that it is a balance against the other assignments a design engineer has. TE 6 also does mention the complex role of a design engineer, having many different tasks to handle.

4.2.2.7 The Relation Between Design Engineer and Simulation Engineer

Today at Scania, the relation between the design engineer and the simulation engineer is that the simulation group act as a support function to the design engineers. It is the design engineer who decides when to order simulation in projects and on which components. Thus, the design engineer is the driving force for the use of technical simulations. TE 5 explains the need as an important factor if a design engineer decides to send a TA to have simulation performed. The need decides how, when and if simulations groups are involved or not.

The relation between the design simulation groups has areas of improvement. There is a wish from TE 3 and its simulation group that design engineers perform simulation such as GAS calculations before they send in a TA to them. TE 3 and its simulation group tries to support the design engineer to perform GAS simulation by written instructions. This support is highlighted from TE 5, which means that help can be retrieved from the simulation groups. TE 7 and TE 8 confirms that it exists support from simulation engineers to help the design engineer with easier simulations. Today there is no standard or requirement to perform simulations, but it would be beneficial to have. It can be seen in TA if design engineers have taken help from simulation engineers and reflected over the design, TE 8 narrates. The simulation group looks through the TA when received to see if there is a possibility to perform the simulation in GAS or similar software because it offers a faster solution.

4.2.2.8 Encouraging Using Technical Simulations

Several factors are mentioned during the interviews with the technical experts as encouraging, these are presented in Table 4.5.

Table 4.5 Encouraging factors for the use of technical simulations

Factor	Description
Wish to get quicker answers and rapid evaluations	This factor is set in relation to the other way of validating a design, physical testing
Wish to gain understanding before physical testing	This factor is set in relation to the other way of validating a design, physical testing
Wish to iterate and optimise the design	This factor is set in relation to the other way of validating a design, physical testing
Wish to reduce cost and time	This factor is set in relation to the other way of validating a design, physical testing
Having validated methods that give trustworthy results	The available methods need to be visible, implemented into guidelines and show employees that simulations are an alternative, or complement, to physical testing
Involvement of technical simulations in processes	To involve the simulations into new project plans and in cross-functional milestones in the different processes
Possibility of automated processes	The automation gives the possibility to involve more people and tools with different competence in new areas
Interest of the design engineer	The usage of simulations is not a threshold in knowledge but the centre of interest as a design engineer. Some design engineers with interest and experience in technical simulations are more prone to use it and to send it to simulation groups but if the interest lies in assembly, production or purchase, simulations can be involved later or not at all

4.2.2.9 Difficulties with the Usage of Technical Simulations

Several difficulties and challenges are presented as well during the interviews. They have been summarized and are presented in Table 4.6.

Table 4.6 Challenging factors for the use of technical simulations

Factor	Description
Scepticism	A thought of low capability and reliability in simulations among employees and the strong belief in physical testing
The role of the design engineer	The design engineer is today at Scania controlling how the use of technical simulations is set and a lack of demand could be seen
Resources	Time and competence must be given to increase the use of technical simulations
Knowledge concerning the simulation groups	Another difficulty in relation to technical simulations is the informational aspect concerning simulation groups that exist and what they do. A reason why the lack of knowledge about simulation groups has occurred is poor communication
Input data	The need of having the right input data to be able to build right and accurate models

4.2.2.10 Advantages of Using Technical Simulations in Product Concept Development

Besides the previously presented encouraging factors and challenges concerning technical simulation, the area of technical simulations and product concept development were discussed.

According to TE 1, the number of available test engineers can encourage to use simulations, if it is difficult to get a physical test performed, the amount of simulations increases. TE 4, TE 9 and TE 10 can see the use of technical simulations in concept development is encouraged by the lack of hardware. Possibilities to make rough estimates on several concepts encourage the use of technical simulations in the concept development with unbiased results, narrate TE 5, TE 9 and TE 10. It could also evade late costly changes when applying technical simulations early. It is easiest and least expensive to make changes early in the development process, narrates TE 2. TE 8 states the following when discussing technical simulations within concept development:

> *Concept development can have great profit from simulations entering early because then you can steer the properties in a mighty way.*

4.2.2.11 Difficulties of Using Technical Simulations in Product Concept Development

According to TE 2 and TE 4, difficulties in using and implementing technical simulations in concept development can be access to tools with the right accuracy and capability. Another difficulty is not having a milestone or something in the concept development process which asks for simulations. It can inhibit the usage of technical simulations since it is up to each one what to do, TE 3 explains.

It can be difficult to simulate early because of the importance to know the boundary conditions, which in concept development have not been set. To be able to perform simulations, matureness is needed, TE 5 narrates. Difficulties using technical simulations in concept development could be the inadequate data leading to time-consuming projects to perform correct simulations. Other factors that can affect the usage of technical simulations are the design engineer’s approach when designing, it is important that the design engineer feel the value of performing and ask for simulations, implies TE 5.

In general, is there a lack of simulation and physical testing in concept development according to TE 4. To be competitive against other competitors it is needed to implement both simulations and physical testing, TE 4 explains.

4.2.3 Design Engineers

In the following section, the answers from a design engineer’s point of view are presented. The created interview guide for the design engineers can be seen in Appendix D. In Table 4.7 presentation and anonymisation of the interviewees are defined. All the participating design engineers have a relation to the concept development process.

Table 4.7 Interviewees – External resources at Scania

Function	*Name*
Expert Engineer	DE 1
Expert Engineer	DE 2
Group Manager	DE 3
Design Engineer	DE 4

4.2.3.1 The Work as a Design Engineer

The daily work for a design engineer varies depending on which department and group they are working at. For all design engineers their job assignments have a wide variety, where some of their daily work tasks are to order physical testing, order simulation, communicate with purchase, have a dialogue with suppliers, ordering articles, take care of all the errors which can arise and needs to relate to, take decisions whether to perform changes in the design and have a dialogue with production. The time spent in CAD varies a lot but to be a capable design engineer is not the same as to be skilled in CAD, DE 2 narrates. DE 1 summarises their work assignments to be too many and too much. It is difficult to become good in all the different areas because the frequency is too low for each task and activity. This thought is supported by DE 3 who finds the number of tasks to be problematic. A design engineer's biggest challenge is to find focus and balance in their daily work. As a design engineer, there is an ownership responsibility focusing on both future developments, involving for example legislation, but also ongoing development.

4.2.3.1.1 Design Engineer Working Agile

To gain further understanding concerning how an Agile Methodology can be applied with technical simulations, the interview with DE 4 had the main topic of Agile operating method and simulation sprints. In the following section, a design engineer's work in an Agile environment at Scania is explained.

At DE 4's group, the operation method is the same for both concept development and product development. When a simulation sprint has been completed there is a meeting where the results are shown, what did or did not work. According to DE 4, the way of working is knowledge building. The advantages by using sprints according to DE 4 is having general TA for the whole sprint and that the TA is always active, it reduces the administrative work of having to send a TA each time when a simulation is requested. The use of a design freeze leads to that the right updated geometries always is being used. The use of the design sprints also gives the advantage of it being easy to get through changes.

A difficulty highlighted by DE 4 is that to be able to work in an Agile environment and in simulation sprints, the role of the design engineer needs to change. This change is required because of their current work tasks are too comprehensive, DE 4 narrates. DE 4 developed its thought:

> *The problem with today's role for the design engineer in combination with simulation sprints is that it requires 100% of the working hours during the design part of the sprints. Due to all the surrounding assignments are not put on hold during the sprints, there is a collision in workload. To be able to work Agile one cannot have surrounding activities, which at any time can appear and claim full focus.*

4.2.3.2 Design Engineer and Product Concept Development

Working in concept development projects, there is a limited amount of people involved and there are almost always the same persons in every project, DE 2 implies. Everyone in the team knows each other relatively well since they have been working together previously. In those teams, they are continuously challenging each other with the determined demands and what they can accomplish so that a balanced product with balanced properties can be found.

4.2.3.2.1 Room for Improvement

Described by the interviewees are some potential challenges and difficulties that need to be handled with the current process. Mentioned is especially the need of having a faster process with a reduction in lead time.

Both DE 1 and DE 2’s points of view concerning the concept development includes a process that needs to be faster. DE 1 believes that one of the reasons being too slow is that Scania is a part of the TRATON Group and in the group of companies, the aim of including everyone takes time. DE 2 highlights that the long development time could be due to physical testing and prototypes and the time it takes to build and perform them. A problem concerning the degree of innovation is also described. According to DE 2, it is rare that something completely new is created in the concept development process type, there is always someone else that has done similar things in prior projects. DE 2 discusses how to create a way of working that encourages innovative solutions and a suggested approach would be the use of co-location. Co-location aims to create teams that can help each other with resources, different opinions can easier be shared, different goals between individuals in the group can create dynamic and a discussion can be stimulated.

4.2.3.3 Technical Simulations Related to Design Engineers

With many and varied work assignments it is difficult to find time to learn and use simulations as a design engineer. However, according to DE 1, more simulations should be performed by design engineers since it is knowledge-building. Design engineers control the usage of simulations, therefore is it important to have an inquiry for simulations higher up in the organisation to encourage design engineers to use simulations. Group managers, section managers and project managers connected to the design work have a central role in the encouragement of using simulations according to DE 1. At Scania today, the work with simulations are too individual and there are no evident rules of how and when a design engineer should request a simulation. TA is used to request simulations and testing but there is a need to have a persistent communication between the design engineer and the simulation engineer concerning interpreting and understanding simulation results, DE 1 narrates. DE 4 confirms that the use of technical simulations is individual and a solution to it could be by improving existing methods with adding tasks where it is necessary to perform simulations, to not give the possibility of choosing by oneself.

4.2.3.3.1 Technical Simulations Within Product Concept Development

The use of technical simulations within the concept development process varies a great deal, both in complexity but also when they are performed, according to DE 1. In today's concept development projects, it can be enough with a competent design engineer to have a look at the solution, narrates DE 1. The interviewed design engineers can see both advantages and difficulties with the use of technical simulations in product concept development. An advantage is the possibility to compare several concepts simultaneously. However, a difficulty concerning the communication between design engineer and simulation engineer arises.

4.2.4 External Informant

An interview was performed with a sprint coordinator, who works at the department of engine development. Interview questions can be seen in Appendix E, to gain further understanding of the modern ways of working at Scania today, the informant further referred to as EI 1.

The informant describes a simulation sprint as structured in two stages: the standard phase and the iteration phase. The standard phase starts with the virtual design freeze and the model at that given time will serve as the model to perform the simulations. A predetermined set of simulations are performed, each simulation is only performed once. The results provide an overview of the product concerning performance and properties as well as maturity. After the standard phase, the iteration phase is performed where the focus is to correct deviations through changing the model. The focus lies on collaboration between design and simulation engineers, and the goal is to iterate as many times as possible. To simplify the quick changes, a TA is not needed to be written each time a simulation is requested since it will be followed up by the coordinator. When asked to describe simulation sprints, EI 1 highlights that the simulation sprints can be considered as a project, where each task is a simulation or some other related activity. The coordinator role is similar in certain aspects to a project manager, with the planning as the focus. Coordination and communication are two major aspects to make the simulation sprints work. EI 1 also point out that in parallel there is a need to continuously improve the process and increase efficiency concerning for example how to collect information from the designers, how to determine the acceptance criteria and the inputs needed (which is of the utmost importance since the results accuracy and interpretation are directly correlated to them), how to plan the dependencies between the activities and how follow-up should be performed. Since the simulation sprint could be considered as a project, the informant has created a shared dashboard to allow efficient communication with different audiences by making available important information about the sprint.

A question is being asked concerning the reactions from the co-workers when implementing simulation sprints, and EI 1 emphasizes that there was a full spectrum of reactions, with different levels of acceptance mainly due to defiance toward simulation results and more trust is given to test results. Thus, it is important to be very clear on the relevance of the results by being transparent on the capability of the methods, also by weighing more the results from highly capable methods and less the results from the methods with lower capability level. The key factor, however, according to the informant, was that the top management is supportive, which helps moving forward with this new way of developing products.

EI 1 are currently in the process of working with simulation sprints in a green process type project. The idea of the sprint simulations started when the informant realized the value of automated technical simulations processes. The automated process could, according to EI 1, reduce the number of mistakes and lets employees work with their core processes. It will also reduce the duration of the process. According to EI 1, the scope of the sprints is to gradually reduce the number of needed physical prototypes in favour of virtual ones. The sprint will build knowledge and product maturity with periodic reference points.

When being asked about the possibility of implementing simulation sprints into a yellow project, EI 1 thinks that the yellow process type is more about building knowledge, focusing on design exploration and investigating the design space. However, the informant has not participated in a yellow project so far and clarifies that the simulation sprints might be able to be implemented, but not in the way they are performed today in the green project. The implementation of simulation sprints has been in a green project at the department the informant works at, this due to the ongoing project were in the green process type.

As a final summarizing question, EI 1 are being asked about how the future of Scania might look, concerning simulation sprints. The informant highlights that the use of simulation sprints is a learning process, but it is the best way of moving forward concerning method development and needs to be implemented on a larger scale. However, other, better, methods might be developed in the future to come. The advantage of implementing simulation sprints, according to the informant, would be that an increased focused on standardized and parameterized models and simulation methods, an advantage that will support and strengthen the potential of moving towards more automated processes which ultimately will hugely increase efficiency and shorten development time.

4.3 Observations

Presented within this segment are the results from the observations with a simulation engineer and a design engineer. The observations were performed according to the previously written methodology.

4.3.1 Observation of a Simulation Engineer

The observed simulation engineer worked in a simulation group at RT where the introduction of simulations sprints has been made. The sprint layout consists of three periods, in a total of five weeks. The first two periods consist of two weeks, the last period is only one week (2+2+1 weeks in total). The aim of introducing this layout of the sprint is that it is easy to adapt to the 4+1 weeks which some of the design groups have used before and which is mentioned in the document study, "Rise of RT". The two-week periods aim to perform simulations and work with ongoing projects. The reason for using two two-week periods instead of one four-week is to simplify planning and getting a better overview of the work that needs to be performed. Improvement work within the group is made in the one-week period.

The transition to work in sprints has been positive and the simulation engineers are optimistic about working Agile. The benefits of working in sprints are the simplicity to plan the accessible time in a shorter perspective and the overview that comes with the planning. It is easier to detect problems early when there are smaller steps in the sprints.

According to the informant, there are difficulties in the communication between the design engineer and the simulation engineer. The difficulties that arise are the gap between the different software tools that design groups and simulation groups use as well as the geographical distance between them. The gap between the software for the different groups is the complexity but also the little knowledge that the other group has for each other's software. Simulation engineers should know how to use GAS to encourage design engineers to simulate more and to be able to act as a support when design engineers need it.

An observation that the simulation engineer has done during its time at Scania is how the TA is handled between design engineers and simulation groups. The design engineer sends a TA when there is a need to perform technical simulations or physical testing. The TA is sent to the group manager at the simulation groups and it is up to the group manager to decide and to plan if the assignments will be performed. According to the observed simulation engineer, this relationship creates a difficult situation for the design engineer, the design engineer must have contact with the group manager of the simulation groups. This hierarchal step could be difficult to overbridge for new design engineers.

4.3.2 Observation of a Design Engineer

The observed design engineer works at a design group within RT and has been working there for three and a half years. The design engineer explains that there are many different tasks a design engineer must handle every day, where some of the tasks are performed at a low frequency. One of them being the use of the simulation tool, Catia GAS. Using GAS is crucial and important to a design engineer according to the observed employee. It is considered that the usage of GAS is a good way to learn how to design better through continuously knowledge-building. Another factor which is encouraging the use of GAS is the possibility of retrieving quick results from the technical simulations in comparison to sending a TA to a simulation group.

Another one of the tasks that a design engineer has is to make two-dimensional drawings. The drawings are then used to communicate with suppliers. According to the design engineer, the drawings are depending more on the suppliers than on Scania. The observed design engineer highlights the possibilities that lie within MBD if it would be fully implemented. This opportunity arises since it reduces the need for making drawings. Getting rid of the drawings would liberate time for the design engineer and increase the potential of conducting other tasks. To be able to fully implement MBD there are big changes needed to be made at Scania, but it is also important that the suppliers are compatible with the usage of MBD. Other tasks and activities performed by the design engineer are, for example, finding space where the components can be placed on the trucks, handling quality problems, estimate and decide the price of components and creating design guidelines. Each design engineer also oversees some sort of ownership and included in responsibility are the development of the roadmaps.

According to the observant, the modularization Scania has is aggravating the work for a design engineer. This difficulty arises since components and systems must be designed to fit several modular solutions, leading to not always the optimal design. On the other hand, there are advantages with the modularisation according to the design engineer. An example is that Scania is more profitable using the system of modules.

4.4 Summarizing Results from Case Study

This master thesis aims to give suggestions concerning activities of change for Scania to increase the implementation rate of modern working methods and the use of technical simulations. To be able to suggest reasonable activities, a problem formulation needs to be stated. From the interviews, five main problems are found, presented in Table 4.8. The reason for choosing these five problems is that they are mentioned the most times according to the performed coding. The number of times a problem is mentioned shows that several parts of the company are struggling with the same challenges. It could also be seen that the five problem areas are presented within the three main groups that are being interviewed; section managers, technical experts, and design engineer. This spread also shows that the problems are relevant to the whole company. The five problem areas are also supported by the performed observations.

Table 4.8 Problem areas and minor description

Problem	***Description***
Lack of explorative space	Clearly described in several interviews is the lack of having a designated process for being able to explore different solutions and working innovatively
Long lead time	The current yellow process is to slow and as described by the interviewees: Scania is to slow in responding to the customers' needs and requirements
Definition of concept	Several struggles with the handling of a concept, the potential of visualising and clearly answering the stated need from the customer
Role of the design engineer	The design engineer today at Scania has a key role in the ordering and initiation of a technical simulation. However, the design engineer struggles with several tasks and activities, leading to a frequency problem
Collaboration simulation and test	There is a lack of collaboration and exchange of support and knowledge between the two groups of simulation and test engineers

5. Results from Benchmarking

Presented here are the results concerning the benchmarking. This segment has been split in two, one for were the answers from the producing companies will be presented and one for the answers from the companies developing software that Scania uses.

5.1 Benchmarking with Production Companies

For the benchmarking seven companies have participated. The questionnaire questions can be seen in Appendix F. The sizes of the participating companies vary between 300 to 45 000 employees and in Table 5.1 the participants are introduced with their position at the company and how they from now on will be referred as.

Table 5.1 Participants – Benchmarking for production companies

Function	***Name***
Simulation Engineer	C1
Manager – Mechanical Design	C2
Inline Manager	C3
Simulation Engineer	C4
design engineer	C5
Development Engineer	C6
Section Manager	C7

5.1.1 Concept Development

The first section of the survey treated concept development where it was asked if it existed any formal description of the process. Six participants answered yes, and one answered they did not know. In Figure 5.1, the result is shown in a pie chart.

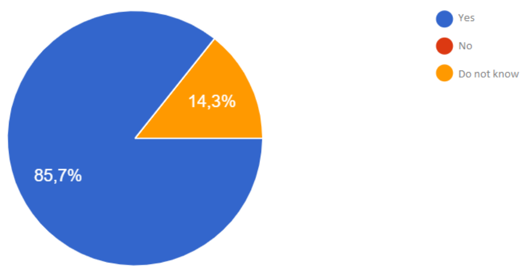


Figure 5.1 A pie chart displaying if there is a formal description of concept development process at each company

For all who answered yes on the question regarding if there is a formal description of the concept development process, everyone said their companies had the process documented. How the different processes were documented was through their intranet, in the product development process, excel sheet in the portal, partly process document and in process description for pre-development.

A question if there is a difference in procedure in terms of traditional or more explorative development projects four respondents answered yes and three answered they do not know. In Figure 5.2 a pie chart over the results of the asked question.

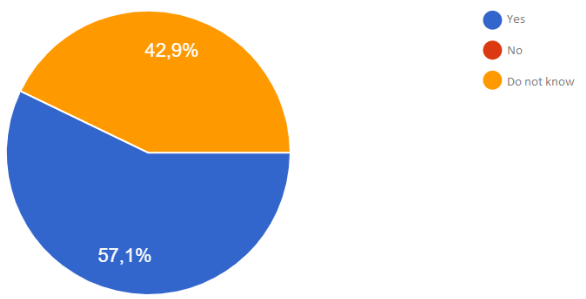


Figure 5.2 A pie chart over the answers if there is a difference in procedure between explorative or traditional development projects

For the respondents who answered yes, they were asked to describe the difference. C1 answers the difference is the size of the project's groups, in explorative projects, there are smaller groups and the involved engineers have a bigger responsibility. C2 describes the difference as in traditional projects there are known solutions where they call them platforms and in explorative projects, the focus is on trying to find solutions. C3 explains the difference to be the use of Model-Based Design in some new projects, but it is depending on where the project is performed in the organisation. C4 describes in the traditional projects there should be no risks but in the concept development and explorative projects, the goal is to find, evaluate and sole risks.

Another question asked was if there was a time difference between traditional and explorative projects, four respondents answered yes and three said they do not know. In Figure 5.3 a pie chart over the answers is displayed.

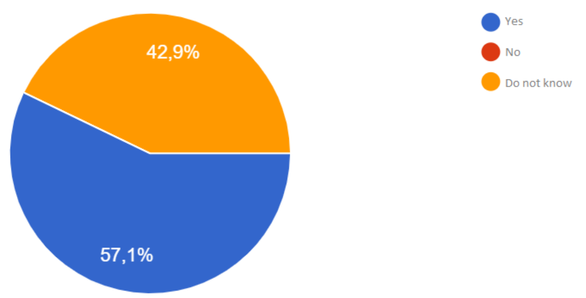


Figure 5.3 Pie chart over the answers if there is a time difference between traditional and explorative projects

If the respondents answered yes it was asked to estimate the time frame for a traditional concept development project and an explorative concept development project. C1 answers for a traditional project the time frame is 12 - 24 months and for an explorative project, it can be 12 - 48 months. C2 answers 36 months on a traditional project and for an explorative project to be 2-6 months when it acts as a pre-study. C4 answers 60 months on traditional projects and 24 months on explorative projects.

It was asked if the respondents think the way of working with concept development today needs to change, four say yes and three say they do not know. For the respondents answering yes it was asked why they think it needs to change, C2 answers that concept development must have dedicated resources. C3 thinks they must "simulate" more in an assembled system level. C4 explains that there is time pressure in explorative projects, and it cannot always be solved with more persons involved. C4 states there is a difference in calendar time and operating time and understanding problems can take time. C5 thinks more explorative development would be needed.

Trends experienced within concept development was different from the companies. C1 and C6 experience more simulations to decrease the amount of physical testing. C2 can see more onward efforts being made in the aspect of simulations. C4 sees the development to go faster and C5 can see the trend of Agile methodologies increasing.

The respondents were being asked to define a modern way of working. C2 sees a modern way of working as clear gates and to follow plans while C4 sees gradual development. C5 describes the modern way of working to daring to step outside the box while C6 describes the working method as simulations are the major part of the process. C7 describes the modern way of working model based, where the starting point is from the three-dimensional-geometry from products and processes but also to use digital and virtual tools, and resources.

5.1.2 Technical Simulations

The second section of the questionnaire treat technical simulations in general. Ansys, Catia, SKF Beast, Creo, PDM, Altair, SolidWorks, MATLAB, Simulink were the most commonly used at the companies and the software are the same independent of which phase the projects are in. Six respondents answered the question: How many different software that are used at the companies, and in Figure 5.4 a bar chart is displayed of the result.

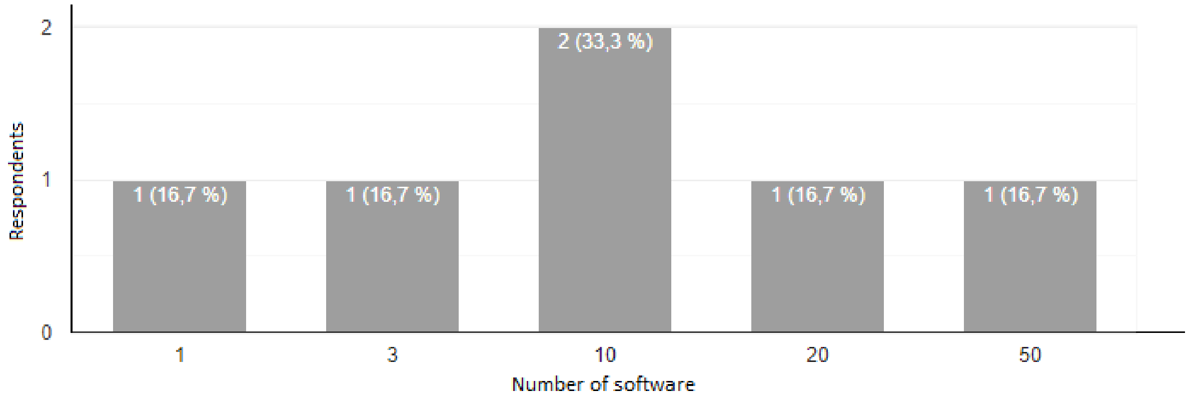


Figure 5.4 A bar chart over the amount of used software at the companies

Education given at the participating companies is an introduction to the software the companies use, and external education and courses with seniors who are working at the company.

Factors that affect the use of technical simulations is individual according to the design engineer and the available resources according to C1. C2 answer knowledge and understanding of the benefits technical simulation can give. C3 and C5 answer the education of software and software is essential and that managers are involved in simulations. C4 sees speed as a factor, the evaluation method is depending on the most rapid way: simulation, building prototypes or performing physical testing. C6 consider development time and detail richness in the results of technical simulations compare to physical testing be affecting factors. C7 finds the asset of complete material and information in digital form as a factor affecting the use of technical simulations.

Factors that encourage the usage of technical simulations according to C1 is that they are incorporated in the processes. C2 sees shorter lead times in project and cost savings as advantages using technical simulations. C3 sees the quality while C4 sees the faster simulation loops and the decrease in resources which saves time and money to be encouraging to use technical simulations. C5 sees simplicity in software while C6 and C7 see the possibility to understand the function of the construction in an early phase. Simulations are fast and simple and can show the maturity before a prototype is built.

Difficulties with using technical simulations according to C1 is the material data and poor CAD-geometries. C2 sees the correlation against reality as a difficulty with technical simulations. C3 and C5 see the drawback of using difficult software, hard to decide the detail level of models to fulfil the simulation assignment. C4 sees the capability as a difficulty with using technical simulations in addition to faith in physical testing. To decided boundary conditions that correspond to the reality is difficult according to C6. The basic data needs to be good enough when performing technical simulations, otherwise is the result not reliable.

A question regarding where decisions according to processes and technical simulations are made were asked. In Figure 5.5, a pie chart of the respondents' answers is shown.

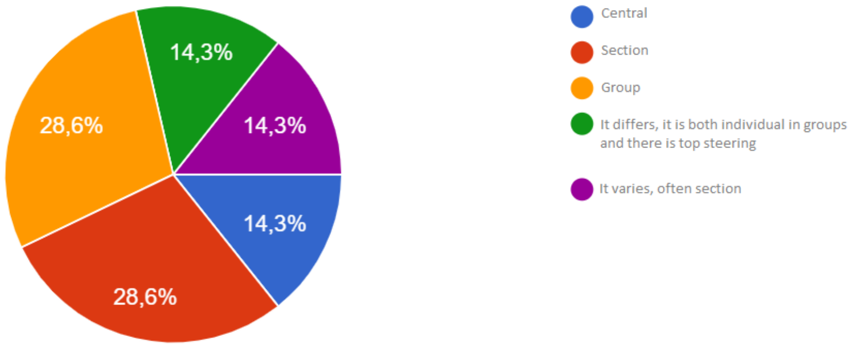


Figure 5.5 Pie chart of how companies decided about processes and technical simulations

A question concerning where decisions are taken regarding software was asked and the respondents' answers can be seen in Figure 5.6.

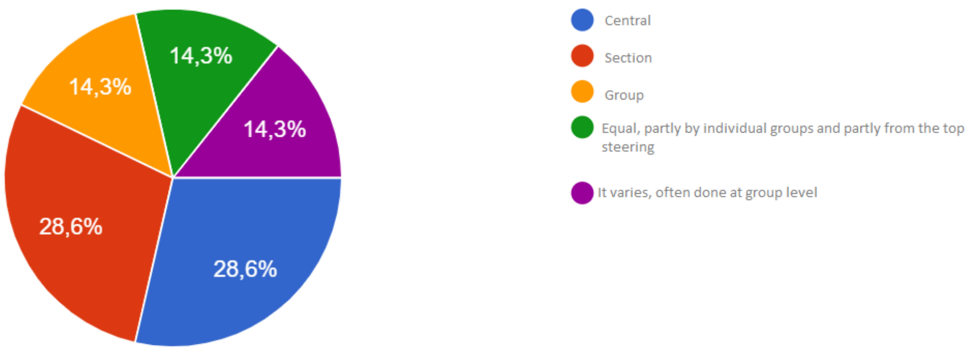


Figure 5.6 Pie chart of where companies decide about software

5.1.3 Technical Simulations and Concept Development

The main answer from the respondents concerning how technical simulations are used in the concept development process was that technical simulations are used to verify, develop and analyse the product early. It is a way to find errors early and to shorten lead times in projects. A question was asked if technical simulations were used evenly over concept development time. The result was five no and two said they did not know. In Figure 5.7 a pie chart over the answers.

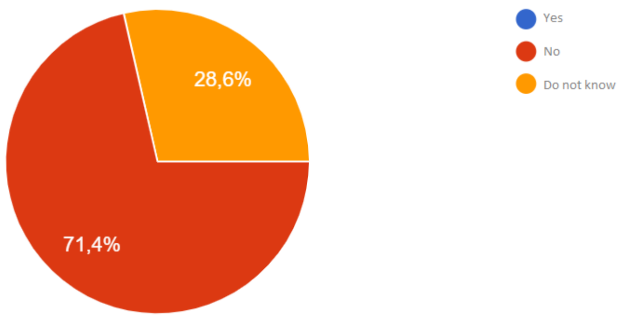


Figure 5.7 Pie chart over if companies use technical simulations even over time in concept development process

The answer to how many people that are involved in concept development projects and are working with technical simulations differed, but the most common answer was 1-2 persons per project. The amount of time spent on technical simulations in concept development projects was asked but the respondents found it difficult to answer because it varies from project to project. It was answered to be 10 % to 30 % of the project time to hundreds of hours depending on what kind of project there is.

Factors affecting the use of technical simulations in concept development is because of physical testing cannot be made due to the product does not exist yet according to C1. C3 implies traditions to be something affecting the usage of technical simulations, it can be difficult to introduce new things in a tight time plan, but over time this will change. C4 sees knowledge about simulations concerning which software is well suited for the purpose and know how to operate simulations as affecting factors. C5 implies that time is affecting the usage of technical simulations in early concept development. According to C6 the effect of using technical simulations depends on if concepts are based on already known solutions or not. If it is already known, the simulation needed is less than if it was a new concept. C7 thinks the access to good ground data digital affects the usage.

Encouragement to use technical simulations in early concept development is individually dependent according to C2. Better and wider knowledge to neighbouring areas sees C3 as encouragement of using technical simulations. C4 sees reduced resource usage as an encouragement and a faster knowledge building can be seen with the use of technical simulations within concept development. To verify that the product function is an encouragement to use technical simulations in concept development according to C5. To understand the usefulness of a concept early without making prototypes is encouraging according to C6. Encouragement according to C7 is to be able to find errors early, shorten lead times, more troubleshooting and optimized product in the end.

Difficulties with using technical simulations in early concept development, according to C2 and C6, are to build correct models and to know the boundary conditions. Different backgrounds and different tools can be a drawback for the usage of technical simulations within concept development according to C3. A lack of time for the persons who can perform relevant simulations and lack of input data is difficulties with using technical simulations early in the concept development process according to C4. Limitations in software and hard to understand software can be difficulties to use technical simulations according to C5. C7 considers the access to correct material data to be essential and many decisions.

How the usage of technical simulations can support a modern way of working were asked and the answers from the respondents were homogenous. Everyone sees simulations as a central role to the modern way of working and to shorten lead times. As a final question it was asked if technical simulation obstruct the modern way of working, where six respondents said no, and one person said yes, the result can be seen in Figure 5.8 as a pie chart.

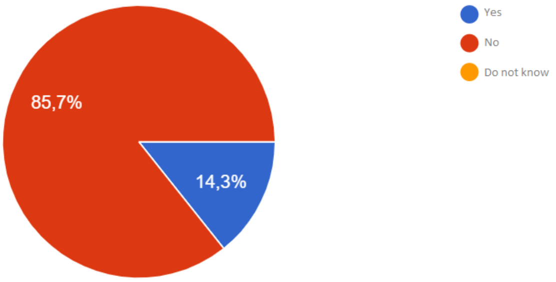


Figure 5.8 Pie chart over how companies consider technical simulations to obstruct a modern way of working

The respondent who answered yes developed their thought: bad input data and knowledge gives incorrect simulation results, which deteriorate the projects. The knowledge by the persons which performs simulations must be high both in the software, input data, and boundary conditions as well as the law of physics. In addition to the mentioned points, knowledge in the simulation system needs to exist, it is also needed to have a critical examination of the results. However, the respondent finishes the reasoning with having capable simulation engineers and a good collaboration the risk can be minimized, and simulations can then strongly improve the concept development process.

5.2 Benchmarking with Software Companies

A questionnaire study was performed focusing on software manufacturers. The asked questions in the survey can be seen in Appendix G. Dassault Systèmes and Altair Engineering are the studied companies. In Table 5.2 the respondents are presented with their title and anonymisation they will be referred to.

Table 5.2 Interviewees in order by function and then name

Function	*Name*	*Description*
External software developer	S1	Area Sales Manager
External software developer	S2	Senior Solution Consultant

According to both respondents their work relates to concept development to a great extent, for S1 the simulation tools the company offer is suitable for that purpose. A follow-up question regarding the trends that can be seen in product concept development was asked and S1 answers that many companies use concept simulations to find the most appropriate ground concept early. S2 describes the trends as an extended focus on software and steering systems.

Both respondents believe the way of working with concept development needs to change. S1 emphasizes the tremendous potential which exists with the use of more simulations. According to S2 the needed change within concept development depends on the demands of silo break down, shorter development cycles and the more complex relationships with suppliers. When the respondents were asked to define a modern way of working within product concept development S1 answered cross-functional, in the meaning of simulations and optimisation driven development. Also, rapid work (sprints performed in days to a week) and multi-physical regarding involving as much information as early as possible in the development works optimisations. S2 shares the same point of view, describing the modern way of working as multilateral, Agile and parallel development with continuous integration.

Technical simulation was a section in the questionnaire where it was asked what influence the use of technical simulations have in an overall aspect. According to S1 the structure of the organisation matter, the collaboration between design and simulation in a company in combination with the technical solution as well as the knowledge about what the technical simulation tools can do and perform. S2 answered accessibility and application handiness together with the demand for shorter lead times and increased system complexity. The encouragement of using technical simulation is described to be the shorter lead times, fewer problems in the late development stages and cost savings by reducing physical testing. Difficulties with the usage of the technical simulations are the organisational structure (relation between design and simulation), lack of knowledge about tools and methods, according to S1. S2 answer break down of demands, data migration between different domains and lack of special expertise as difficulties.

According to both respondents, the persons who are using technical simulation software are design engineers, simulation engineers, and analysts. S1 and its company offer several educational exercises to the software they supply but also in methods connected to their tools. S2 also provides product training.

As a software supplier, both respondents consider themselves to have a responsibility that the integration between different software must work. In what way they have responsibility is, according to S1, that they need to offer communication between different applications because it is necessary to find an effective workflow with maximum flexibility to their customers. The solution is therefore to offer their software to be open to other suppliers' solutions. For both companies, there is some form of categorisation of how advanced their software is. Both respondents divide the software according to different domains and S2 explains how they have a categorisation of which software is more fitting according to if you are a design engineer or a simulation engineer.

The last segment of the questionnaire was about technical simulation in concept development. Where S2 sees the use of technical simulations in concept development to rapid up the development cycles, S1 answers optimisation.

Factors which affect the use of technical simulations within concept development is according to S1 the lack of knowledge of their vigorous software and fast optimisation tools. S2 consider simplicity and availableness as influencing factors. What encourages the use of technical simulation within concept development is the potential to save much money and to increase the performance of the companies' products according to S1. S2 thinks the fearfulness of choosing the wrong concept track encourages the use of technical simulation. Difficulties to integrate technical simulations within concept development are the lack of knowledge at the product developer according to S1 due all the knowledge and tools exist at the software supplier. S2 mentions the tradition of previous working methodology and organisation as difficulties and the simplification of physics for steering system development.

Both respondents agree that technical simulations can support a modern way of working, saying that the usage can be in all different ways. As a follow-up question, it was asked if technical simulation could aggravate the development of a modern way of working. One said yes and the other one said no. The respondent who said yes motivates it as if simulation methods are used in a wrong way, for example using too complicated calculations in the concept process type, the process will be slowed down instead of rapid up. It is necessary to perform adequate simplifications in the analysis within the concept development process type.

6. Discussion

In this segment, the analysis together with a discussion regarding risks and delimitations are presented. Activities of change are suggested concerning the process, organisation, and automation at Scania. The discussion concerning risks and delimitation is in relation to Scania's modular thinking, the symbiosis of the traditional and modern way of working and the simulation trend. The chapter will be closed with a minor discussion concerning the shortcomings of the methodology.

6.1 Short Term Activities of Change

Presented in this segment, several activities of change will be suggested to move Scania towards a modern way of working with concept development and technical simulations. Important to mention before the activities of change are introduced is that Scania today has good working methods and a traditional way of working is not necessarily inadequate. These suggested activities of change could also serve as guidelines for areas to improve and one should be weighing the potential risks with the positive outcome of implementing changes.

When the interviewees are being asked about how they would define a modern approach to product concept development, the idea of working Agile is mentioned repeatably. There exists departments and section within Scania were the use of Agile Methods have been implemented, for example through the "RISE of RT", seen from the document study. Another dimension of a modern approach, as seen from the interviews with the section managers, simulation engineers, and design engineers, is the positivity towards simulation driven development and the strong belief that the direction of simulation is the future. Therefore, the combination and usage of Agile methodology and technical simulation would be a preferable way to move forward.

However, the needed activities of change that require to be implemented could be challenging to conduct. Experienced from several of the interviews is the lack of time to perform changes in process methodology. Moreover, Scania is facing two major challenges, electrification, and automation of their products, which requires both time and resources, leading to a prioritization of those challenges and methodology development falling behind. For example, the Agile methodology that has been suggested has not been implemented to the extent that is needed to transform Scania into a company that has a modern approach towards concept development.

In this analysis, however, the focus will not be on the time required to implement the changes that are needed to work Agile with simulations. Instead, difficulties found within the current process and organisation will be presented to fulfil the aim of this thesis: create methodology prerequisites and encouragement for modern working methods supported by technical simulations, to potentially improve exploration.

6.1.1 Process

After conducting the interviews, three difficulties appeared within the current process, seen in Figure 6.1. As several of the section managers, technical experts and design engineers highlight during the interviews, there is a lack of innovation in the current yellow process and a concept is chosen too quickly without assessing several solutions. Sufficient time is not put on design exploration. As previously mentioned, Scania's focus has been in exploitation and the idea of waiting for the technology to be sufficiently developed before implementing it into their organization. However, to stay competitive, several of the section managers and technical experts means that there is a need for enhancing exploration at Scania. The second difficulty was that the interviewees experienced the yellow projects at Scania taking too much time, the lead time of the projects was between 6-24 months. The last difficulty discovered was the unclear definition of a concept, some of the section managers saying it is too strict while others highlight that the term is too abstract. Technical experts mentioned problems with knowing when a concept is ready and what a concept is. The difficulties are chosen based on the results from the interviews and the number of times that the problem is mentioned.

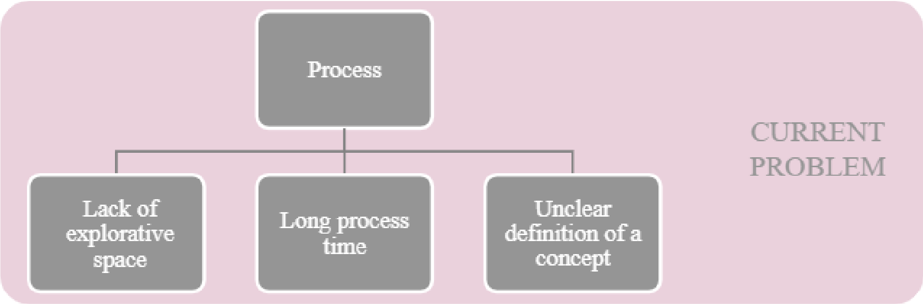


Figure 6.1 Contretized problem of the current process

6.1.1.1 Implementing an Orange Arrow Prior to the Yellow

The three found difficulties within the process could be solved by inserting an arrow prior to the current yellow at Scania. There is a lack of explorative space, and changes must be made to create an ambidextrous organisation, an organisation that focuses on both exploration and exploitation. In the already existing yellow arrow at Scania today it exists the activity called AD, which aims to work explorative and generate concepts at the beginning of the concept development projects, but from the interviews is it told that the exploration is not sufficient. The idea of implementing the orange arrow before the yellow is to lift the activity AD out of the yellow process type to create an own process type with a greater focus on exploration and generation of many concepts. This idea of creating a creative space is supported by the literature review that has been done. The new R&D product development process would look as in Figure 6.2.

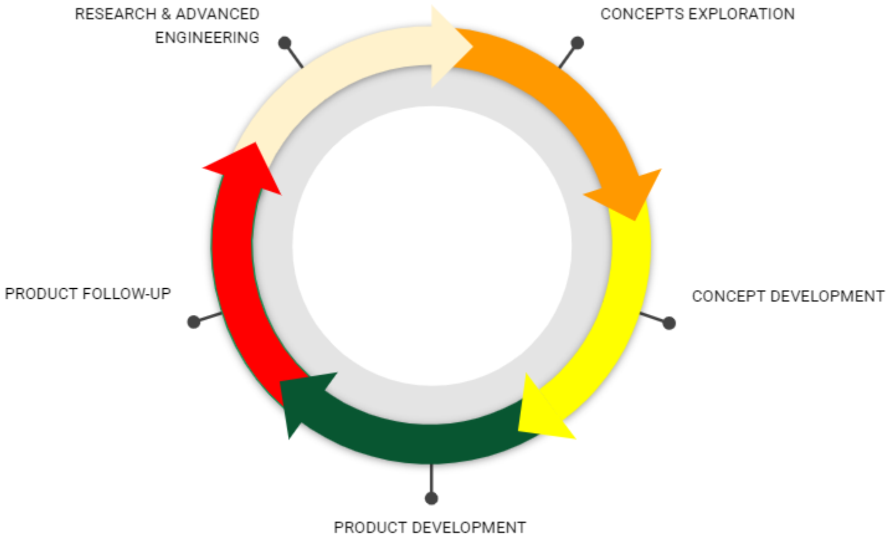


Figure 6.2 Suggested new approach to the process of concept development

The orange process type would aim to focus on an explorative approach, a creative arena to test extremes. The idea of this process type would be to generate several concepts within given requirements and restrictions, a converging approach to finding concepts. The orange process type is optional and will not be used when it does not suit the purpose of projects. This methodology can be seen in the Double Diamond process, that the convergent process type with generating concepts needs to be performed prior to selecting. The current yellow process type at Scania experience problems with choosing the concept too quickly and not having explored the solution space sufficient. The methodology of Design Thinking also has interesting aspects that could be applied to this process such as the ideate stage but also to clearly define the problem before the development start. The similarity between the Double Diamond and the Design Thinking is that an explorative process must be done, before evaluating and selecting the concept to move forward with. The specific methodology for brainstorming and creating concepts have not been investigated further but it could be seen that several dimensions of Agile methodology are applied. Such as iterative, cross-functional, knowledge-building and working flexible and efficient.

The team members for the orange process type project group would be a combination of design, simulation and test engineers located together during the short amount of time required for an orange project, working in co-location. The suggested co-location would be to form a project group that is geographically located next to each other, working intensely under a shorter period, the work would be performed during a couple of weeks not longer than a month. The group should not have other tasks during the orange project, instead fully focusing on the tasks that should be solved. Since Scania, as previously mentioned, is a company with a focus on physical testing, it exists a large amount of knowledge within the staff working at the test departments. They should, therefore, be incorporated into this process type to contribute and forward the knowledge to the design and simulation engineers. Simulation tools that should be used are limited to what the design engineer could perform with the support from the simulation engineer, example on simulations which can be used are Catia GAS and topology optimization. Technical simulations should be used in the orange process type due they are a powerful tool to use early according to the technical experts.

The second process type, called the yellow arrow, would be focusing on assessing and validation of the different concepts and selecting one to move forward with based on criteria and requirements. The focus would also be on further development and design of the chosen concepts, as it is done today at Scania. This yellow arrow is focusing on being the divergent process type. To validate several concepts, it will be done with the use of technical simulations, where the simulations are performed by simulation engineers. In this process type, the technical simulations need to have higher accuracy than in the orange process type, but the accuracy does not need to be on the same level as in the product development process.

The yellow process type would be like the current yellow at Scania, with milestones and follow-up meetings to fulfil Concept Ready at the end of the process type. However, the idea is that the yellow process type would benefit from the Agile working method retrieved from SCRUM, the sprint. The suggested sprint would influence the whole project in the yellow arrow, regarding design and technical simulations together with planning and follow-up meetings. The purpose of implementing sprints is to change focus, to be able to break down the problem, simplify the planning and working with timeboxing. The use of sprints enables to balance and compare properties that are needed to be included in the concepts of the project. It could potentially be interesting to investigate the application of Lean methodology in the yellow process type since it would be focusing more on a streamlined approach.

It is not necessary to include all the properties in concept development since the wholeness of the vehicle is not of high priority while working on concept evaluation. The importance of the concept development is to understand where the concepts are heading and if the ideas are sufficient. To select the most well-suited properties for the sprints to focus on, a priority list could be beneficial, where the list contains the properties which are of interest during the performed project. Using sprints in the yellow arrow concedes to get a comprehensive picture of created concepts and shows the degree of matureness of the product. The idea of sprints is thoroughly described in the interview with EI 1.

6.1.1.2 Clarifying the Definition of Concept for Orange Process Type

To be able to insert an orange arrow prior to the yellow one, there must be a clear aim of what the orange process will hand over to the yellow. Seen in the interviews with the section managers, the idea of Concept Ready, currently the assessment point of the yellow process, is defined. Each section manager has an overall understanding and idea of the aim with Concept Ready. This stage-gate helps taking decisions concerning when a concept is prepared to exit the yellow process type and move into green, industrializing, process type. The idea of the orange process type would be that several concepts are supposed to leave the process and be implemented into the yellow process type. What is needed to be done, is to define what a concept would be. Suggested in this analysis is to use digital demonstrators. The use of digital demonstrators is in line to digitalize the process and methods within Scania today. The term demonstrator has been briefly explained in the literature review and serve as a tool to test functionality and visualising the design and would clarify the term concept. When leaving the orange process type, a digital demonstrator should have been created for each concept to answer the stated need from the customer.

6.1.1.3 Advantages of Implementing Process Changes

Implementing the suggested activities of change will lead to several positive effects. To begin with, by looking at the implementation of an orange arrow before the yellow, three advantages, concerning previously stated difficulties will be presented. A brief overview can be seen in Figure 6.3.

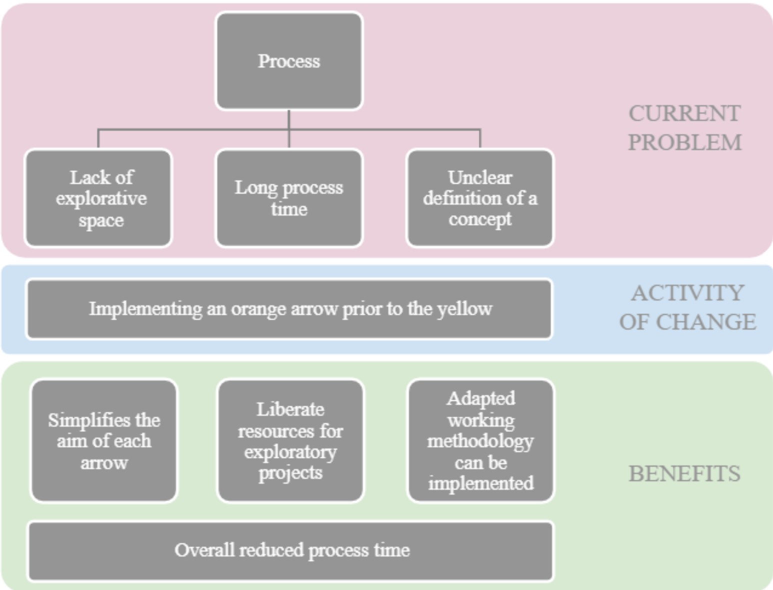


Figure 6.3 Benefits from implementing an orange process type prior to the yellow

The first advantage of the implementation of an orange arrow prior to the current yellow is that the aim of each process can be clearly stated. The explorative part can take a bigger place than it has done previously and it simplifies the understanding concerning how technical simulations should be used and applied, as well as simplifying the implementation of the right simulation tools. The use of technical simulations during the orange process type can promote explorative and innovative solutions since several concepts can be investigated at the same time. By performing other simple technical simulations, the design engineer will also build knowledge continuously. The orange arrow will open the possibility to use technical simulations early and can decrease the time spent in the concept development process type.

In addition, by implementing a new arrow, it will become easier to know and plan how resources will be allocated in projects performed in orange and yellow arrow, regarding investments and employees. With the implementation of an orange arrow, the workload is easier to overview and gives the possibility to secure resources. The set-up today does not allow the responsible at each group to be given specific resources when working with exploration.

The effect of adding the orange arrow into the process results in the possibility to adopt different working methods in orange and yellow which would be complex if only one process type existed. Agile Methods are, as seen from the literature review highly preferable when working with implementing innovative processes. However, when the aim is design exploration, the use of sprint methodology is not recommended, as confirmed by the external informant. Therefore, other methodologies would be more suitable for the orange phase, such as Design Thinking and Double Diamond. Starting by looking at the methodology applied in the orange process type, the co-location of the physical resources during the exploration in the orange arrow could serve as a major advantage. As experienced during the interviews with the simulation engineers and the design engineers, there is a large gap between the two groups, both knowledge-wise, geographically and concerning the software tools that are being used. The co-location is stimulating cross-functionality and the opportunity to integrate technical simulations earlier in the concept development projects. It could also potentially increase the degree of innovation since co-workers with different background and knowledge come together and cooperating.

Methodology changes within the yellow process could also be beneficial, the use of the sprint is well-suited for a validity check within the yellow arrow. The idea of having a design freeze reduces the risk of having changes made to the model when the simulation engineer will perform calculations. The standing TA for each sprint within technical simulations would also reduce the amount of administrative work for the design engineer. Several of the simulation groups that have been interviewed have already implemented the use of simulation sprints in the current yellow process type at Scania and are positive of outcome. Implementing sprints in both design and simulation groups simplify planning the upcoming accessible time since a breakdown of the problem is done. The breakdown and easier planning generate increased effectivity, due to the work being more focused and concentrated. With continuous follow-up after each sprint, concerning design and simulation, the maturity of the project and product can be trackable, and status assessed. The implementation of sprints encourages the use of MBD and single source due to it is important to use the same model while constructing components and products as well as in running technical simulations. However, the full possibility of implementing simulation sprints together with MBD has not been investigated since it is not within the scope of this thesis.

The aim with the split of the current yellow process is, even though one arrow has become two, that the overall concept process time can be reduced. This reduction of time is due to each arrow having a better focus and limitations as well as explained aim and process methodology.

Moving forward, the other suggested activity of change is the implementation of using digital demonstrators as concepts. Three improvements with this change will be presented and a brief overview can be seen in Figure 6.4.

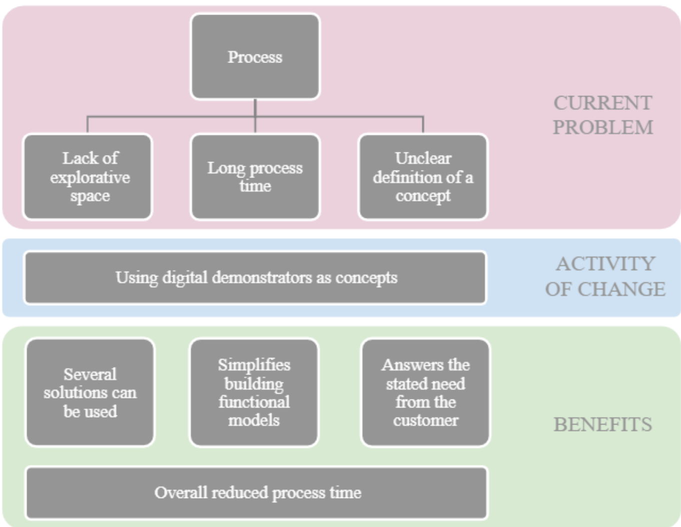


Figure 6.4 Benefits from using digital demonstrators as concepts

One of the problems discovered in the current process is the lack of explorative space. Digital demonstrators could contribute to the degree of innovation since several concepts can be kept in the loop at the same time due to there is no need for producing physical prototypes. Using digital demonstrators and early building demonstrators could promote the innovation degree by clearly showing the appearance of the concept.

A second advantage of using digital demonstrators as a concept is that it supports and simplifies building functional models. Previous in the history of virtual modelling the DMU has been used, where it only has been a nominal geometric description of products. By using digital demonstrators instead as concepts, the possibility to show and test embedded functions as well to evaluate properties in several different domains can be accomplished. In addition to being able to see how the product functions and not only have a visual three-dimensional CAD model, a deeper understanding of the concept can be experienced. The use of digital demonstrators can also be advantageous from a sustainability perspective. Functionality can be communicated within having to build physical prototypes, requiring material and tools.

The use of digital demonstrators would promote and enhance the possibility to work with and implement MBD within Scania. MBD is a functional digital demonstrator that supports the denominations of a single source and a single source of truth, which intends to have all the data and information stored only once. With the use of MBD, the workload for a design engineer would decrease, due to the need to create drawings disappears. The liberated time for a design engineer can be applied in better development of digital demonstrators or focusing on technical simulations. Using digital demonstrators and MBD are encouraged by the possibilities to try functions on the concepts, which is not possible when using DMU.

With the two mentioned advantages above it shows that digital demonstrators with the function of the model answer the stated need from the customer. The usage of digital demonstrators serves as a key factor to support disruptive and ground-breaking development. To summarize, by implementing digital demonstrators, several positive effects can be seen, and Scania takes on one of the large global trends, digitalization.

6.1.1.4 Difficulties with Implementation of the Process Changes

Since there are major changes suggested to be implemented concerning the R&D product concept development process, difficulties must be faced. There is already an initiative to work more Agile at the department of RT, however, due to a lack of time and resources the needed changes have not been implemented. The split aims to create better processes and goals for each arrow, nevertheless there is a risk of it still being too vague and that excessive work is being done. The usage of the orange process is optional, depending on the aim of the project, but having it elective can impede the implementation of the new process type. This difficulty arises since it gets individual deciding whether the orange process should be used or not. Another difficulty which is of great importance is that the quality of the different technical simulations software varies greatly. Which in other words means that the capability and reliability are diverse.

Implementing new ways of working can be problematic, due to the mindset employees with influence have, for example, managers. Managers are responsible for implementing changes and from the conducted interviews it could be read that the interest in changing the way of working differs depending on who is being asked. No changes can be done if there is no interest from the managers in different departments, sections or groups. Another difficulty is that the department RT is large and handles a complex part of the truck, chassis, leading to many people being involved in the projects and trouble anticipating design aspects.

Another difficulty is the relation between MBD and explorative concept development, MBD can sometimes be difficult to use for explorative purposes. The use of MBD is a possibility but is not necessarily the only valid solution, more research should be done within that specific area. The two suggested process changes would also be needed to be further investigated with both, for example, risk analysis and lifecycle analysis to gain a deeper understanding of the implementation.

6.1.2 Organisation

Retrieved from the interviews, two organisational difficulties were recognized, seen in Figure 6.5. In the centre of both performing simple simulations as well as requesting technical simulations, is the design engineer and the role of the design engineers is a problematic and dated role. The role is however interesting since the incitement of performing a technical simulation is conducted by the design engineer and is therefore crucial for the use of technical simulations. The role that is currently filled with several tasks, dealing with an overall frequency problem. Each task is not performed often enough according to interviewed design engineers, technical experts verify the high number of different tasks a design engineer has. For the section managers, they are informed of how the working environment is for design groups and know about the widespread of different tasks. The role contains several dimensions, including administrative work, designing aspects and having the major balancing responsibility between all the stakeholders. The stakeholders' requirements need to be assessed against each other and balanced correctly. Some of the tasks that are performed are not executed continuously. One of those tasks is conducting simulations, and as described by the section managers, technical experts and design engineer the simulations are performed if the design engineers are sufficiently confident and interested in performing the calculations. The role of the design engineer can, therefore, be individualistic, especially regarding technical simulations. The current situation relays on the fact that the design engineer is having an own interest in performing simulation, for example by taking the electable course with GAS at Scania. The calculations that could be performed by a design engineer, before handing over to the simulation engineer, are therefore not always done.

Another difficulty to be seen in the result where the lack of collaboration between simulation and test engineers. It was told during the interviews with technical experts that the communication between test and simulations was non-existing. Technical simulations and physical testing are operating independently of each other, where the design engineer requests the different assignments and decides whether to perform a technical simulation or a physical test. All communication between the three parts is handled by the design engineer. From the conducted interviews, the strong tradition of physical testing at Scania has been mentioned recurrently from section managers, technical experts, and design engineers. Employees see physical testing as security. The great knowledge that exists at the groups for physical testing and technical simulations are highlighted by technical experts and section managers and it is a drawback not to share this in a greater extent. The knowledge should not only be used as a support function to the design engineers.

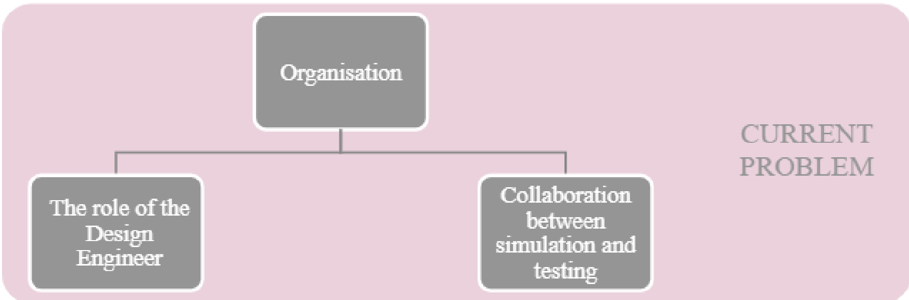


Figure 6.5 Contretized problem of the current organisation

6.1.2.1 Splitting the Role of the Design Engineer

The problems surrounding the role of the design engineer: many tasks that need to be performed and a too individualistic approach on which tasks that are going to be handled, could be solved. The idea is to split the role of the design engineer into two. The idea arises during the interviews with the section managers and is supported by the interviews and observation conducted with design engineers. One person must maintain the balancing role, but that person does not necessarily have to perform the strategic processes as well. By splitting the role of the design engineer to one strategic, in charge for example of the roadmaps and price calculations, the other person could work operatively, participating in development projects of the component and balancing the stakeholders' requirements. The split of the role is also encouraged by the different interests a design engineer has, today there is a diverse field of interest they can focus on. Therefore, the division of the role could enable new career paths for different design engineers. The idea of the strategic design engineer is that there will be approximately one or two of them at one group, depending on the size of the team. The idea is also motivated by that there are fewer strategic than operative tasks to perform. To give a fairer representation of the tasks the strategic design engineer will perform the role could be called technical object leader.

6.1.2.2 Increased Communication Between Simulation & Physical Testing

The suggested activity of change would be to create a layer structure of communication of the three parts: design, simulation, and test engineer. The idea of the layer structure is that the design engineer requests assignments to simulations group which in collaboration with test groups decide whether to perform the asked assignment as a simulation or a test. A brief overview of the structure can be seen in Figure 6.6. This structure would differ from the previous arrangement where the design engineers were in the centre, controlling the communication with both simulation groups as well as testing groups separately. The idea would be that the base of the layer structure lies within property driven development. Each simulation group would oversee a certain given property that can be investigated for each part or system. If simulations could not be performed, physical testing is required related to the specific property.

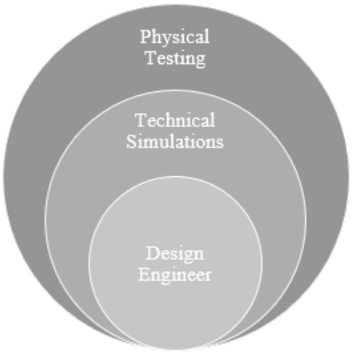


Figure 6.6 Layer structure of how TA will be assigned to encourage a greater collaboration

6.1.2.3 Network with Companies in the Forefront of Simulation Driven Development

According to all the respondents from the benchmarking, the use of simulation tools is a trend seen in product concept development methodology and the use of simulations is taking a bigger role than it has done before. The usage of technical simulations is needed because of the demand of having shorter lead time, less physical testing and to decrease costs. Scania could, therefore, benefit from a network with companies that participated in the benchmarking but also other companies, which have a strong belief in simulation-driven development. The idea is creating a network with focus groups, meeting to discuss potential solutions to the problems that the industry currently is facing. The network should exist in the way that there are a few meetups every year where discussions are held concerning changes and improvement and thoughts are shared about how simulations can be used in the development stage. The responsible person for organizing the network should be neutral, such persons can be found from universities.

6.1.2.4 Advantages of Implementing Organisational Changes

Three advantages can be seen by implementing the organisational changes, a brief overview can be seen in Figure 6.7.

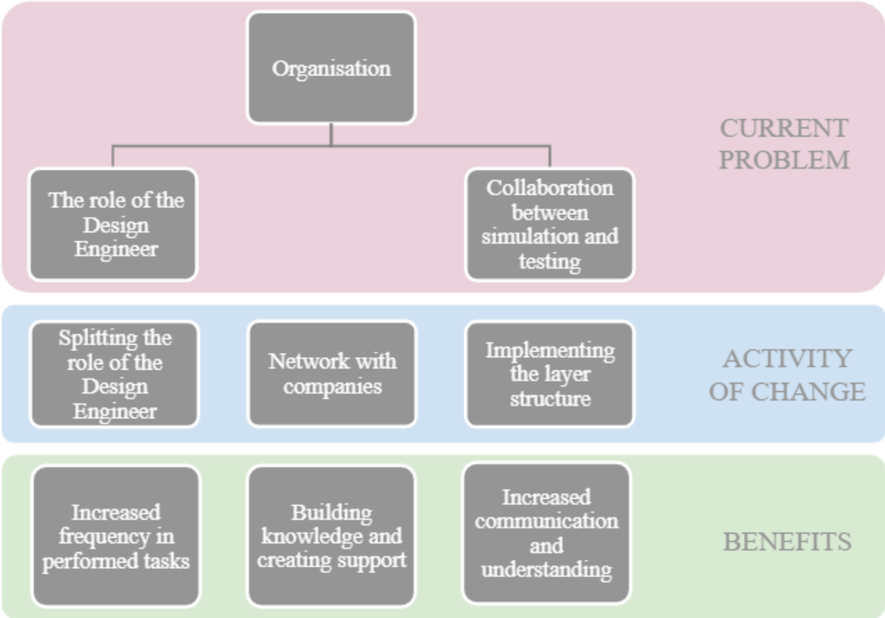


Figure 6.7 Benefits of implementing the suggested activity of changes concerning the organisation

With the suggested split, each design engineer will conduct their task with a higher frequency. In addition, the split of the role of the design engineer would lead to better conditions for working Agile. As seen in the interview with the EI 1, the simulation sprint process is divided into two parts, the standard, and the iteration phase. DE 4 emphasizes that to be able to work fully focused during that second sprint, the workload of the design engineer must be reviewed, which the split would accomplish. The split would contribute to the operative design engineer improving their skills concerning technical simulations. In the Master Thesis written by Johansson & Sätterman (2012), it is seen that a design engineer could perform simple simulations on their own if there is less administration for them. With the split of the design engineering role, the operative design engineer could become more confident using different simulation tools and ongoingly build knowledge. The split of the design engineer's role is supported by the observation of a design engineer.

A network would be beneficial to be able to spread knowledge, share experienced challenges as well as perform changes and put pressure on software distributors. It would be an opportunity to share and improve processes around technical simulations and the usage of them. One of the challenges companies face is how simulation and physical testing interact with each other, which can be discussed in the network. From the results of the benchmarking with producing companies more than half of the respondents have a documented process of product concept development, which could be discussed concerning how technical simulations are implemented. A network would also stimulate meetings with different people with other backgrounds who can share knowledge and experience since members of the network could be both design and simulation engineers.

The change of creating a layer structure of communication will utilise the knowledge within technical simulations and physical testing and the communication between design, simulation and test engineer will increase. The suggested activity of change strengthens TE 4 and SM 5 opinion that there is a need to use technical simulations and physical testing in association with each other and SM 3 highlights that the simulation groups are often integrated too late in the concept development projects. The suggested structure would encourage and support simulation-driven product development. The suggested layer structure would prevent and decrease the gap between the design engineer and the simulation groups as well as the test groups, both regarding knowledge and software and it supports a new way of communicating. The layer structure can be incorporated with the operative design engineer, suggested in the previous section about splitting the role of the design engineer. For the operative design engineer, this structure reduces the amount of TA that needs to be sent out as well as improving the communication and collaboration between the different groups. Another advantage for the operative design engineer is that there is less work to perform, due there is no decision to make whether there will be a simulation or a test. This suggested activity of change would support the idea of a cross-functional organisation as well as knowledge building for all the participating groups. The layer structure would open to working more proactive within the groups of design, simulation, and physical testing. The results of working pro-active create a more positive picture of the collaboration instead of only working with each other when things have gone wrong, which can be seen from the observation with the simulation engineer.

6.1.2.5 Difficulties with Implementation of Organisational Changes

When implementing the split of the design engineer's role, there will be challenges and difficulties arising. A crucial factor that will affect the outcome of the split is how the communication of the different design engineer roles work. Since all the work is performed by one member of the staff today, there will be a need for good collaboration to make it work. It is most likely that each person will have to take care of more than one component to ensure that Scania does not need to hire new co-workers. Due to an increased number of employees, it will raise the cost for the company and the business will not be lucrative.

To implement a network between several companies located in different parts of Sweden can be troublesome. For example, the geographical position for the members and which persons that will be invited to join the network could be challenging.

A problem that can occur with implementing the layer structure is that the design engineer can get lost in communication with simulation and test groups. The operative design engineer will have a central role in the concept development process and needs to have information and knowledge about results from technical simulations and physical testing. It is, therefore, crucial to continue involving the operative design engineer. Such involvement can be during the proceeding of the simulation or physical test and having meetings during the projects. Involving the strategic design engineer within the layer structure can be done by incorporating them in the lessons learned meetings, participating in the evaluation work of how it can be done better in the future. By involving both types of design engineers, their knowledge will be built within the areas and a better communication created.

An overall difficulty of implementing the organisational changes is that the department of RT is large and that their field of responsibility is complex. Therefore, performing changes can be difficult and can take a long time. Another overall difficulty is that Scania is a part of TRATON Group and changes within Scania can be needed to be adapted to the corporate group.

6.1.2.5.1 Change in Mindset

It can be seen in the interviews that Scania has traditionally been focusing on the exploitation aspects when developing products. The same way of working has been applied to all process types and since the focus has been on green projects, the methodology has been applied to all three process types. To stimulate the implementation of changes, Scania might want to consider introducing regulations to push the development forward. Shifting the focus toward exploration and creating innovative solutions require changes. By, for example, requiring, when exiting the orange arrow, at least five concepts needs to be presented. This example would drive the explorative simulation development forward regarding a simulation-driven concept development.

Stated in the interviews of section managers, technical experts, and design engineers is that a difficulty of implementing technical simulations is the strong belief in physical testing and that the attitude is a contributing factor of not implementing changes. Changing the mindset into performing virtual testing instead of physical testing is a complex step to take, requiring the right knowledge within the company and trustworthiness to the results. Since there are restrictions for the technical simulations concerning capability and reliability, Scania is most likely to experience a transition period, going from testing to simulation driven development.

Changing the mindset of a company the size of Scania takes time and is both complex and difficult. To succeed, every co-worker must take responsibility, even though it might be difficult to find time to work with methodology development. Other areas will have to stand back, both time-wise as well as resourcewise. Nevertheless, during the interviews, a widespread understanding of the need for implementing changes to reduce the lead time is discovered. Respect towards the different parts of the company is crucial and understanding of each and everyone's contribution to the new process is needed. The transition phase will require good communication and collaboration to succeed with the implemented changes.

One of the global trends that are affecting Scania is the digitalization of the industry, which clearly is a part of Scania’s R&D strategy. In the strategy, it can also be seen that “more simulations” is an aim. However, this definition and goal must be clarified to be able to implement more technical simulations than it is today. There is a need to have a concretized understanding of where the company is heading since this can help to unite the organization. The gap between each co-worker and the strategy must be reduced, preferably done by the manager at each department and group. Section managers have a responsibility and the possibility to influence the use of technical simulations and the way of working. If the mindset is changed within section managers, it is possible to change the mindset of the employees working for the managers.

A change in mindset internally at Scania is a must, but it is also important to mention that the mindset of the suppliers to Scania needs to change as well. To be able to focus on simulation-driven development and digitalization of the industry, Scania’s suppliers need to adapt to the transition and change. From the performed observation with the design engineer, it was told that some of the suppliers could be able to manage only three-dimensional parts with no two-dimensional drawings and the others are not there yet. Therefore, a collaboration between Scania and suppliers is needed to perform a change in mindset. In other words, a new mindset internally and externally encourages simulation-driven development and support a modern way of working.

6.2 Ongoing Activity of Change

Within the previously mentioned areas, process and organisation, concrete changes are suggested. However, within Scania today, there is an ongoing activity of change happening.

6.2.1 Automation of Technical Simulations

At Scania today, there is a heavy workload for both design engineers as well as simulation engineers, according to the performed interviews. From the conducted interview with EI 1, it was told that there are many tasks to handle when working with simulation sprints and technical simulations overall. While working with simulation sprints there is a need to work in parallel with tasks such as continuously improving the process, collecting the right information from the design engineers and increasing capability and reliability of already existing methods. A way to decrease the amount of work as well as conducting process optimisation is the implementation of automated technical simulations. This idea is supported by TE 8 and confirmed by TE 4 among others. EI 1 highlights that the implementation of automated technical simulations would help to reduce the number of mistakes during performed simulations and the duration of the process could be decreased.

Automation of technical simulations should be performed in both the concept and product development, due to the software used to perform technical simulations that are the same for both process types. The difference in applying automated technical simulations for the process types is that the purpose, prerequisite, and the detail level is different between the processes. The details are less in the proposed orange and yellow process type in comparison with the green process type.

The major advantage of continuously implementing the automated technical simulation processes is that it supports the previously suggested activities of change. The lower threshold that is created with an automated process is encouraging more people with different competence to use technical simulations and encourage knowledge-building. In orange and yellow process type, automated technical simulations can be performed fast to see if the concepts are heading in the right direction or not and reduce the development lead time. For the simulation engineers, the automated technical simulations can give time to develop the processes as well as building new automated processes and to work with methodology development. Time is also given to increase the capability in the results of the technical simulations as well as to secure the quality. Implementation of automated technical simulations can decrease or eliminate the existing gap between the design engineer and simulation engineer concerning software. From the interviews, it was highlighted that one of the problems between the usage of technical simulations was the substantial difference in software for the different engineering roles.

6.2.1.1 Co-location of Software Resources

To achieve the continuous implementation of automated technical simulations, requirements must be put on the simulation tools used today. The use of simulation tools is, as seen by the interviews, locally chosen and controlled. The widespread of resources could cause trouble when performing sprints. Scania would benefit from a central unit that controls and works with simulations tools, this to gather knowledge and securing and controlling the need for interfaces that can integrate. The co-location of software resources encourages the cross-functional collaboration between simulation groups as well as sharing and building knowledge. The co-location gives an overview of the accessible software and tools that can be used within Scania, in addition to the information of what available methods and processes there are within different software. Having access to that information can prevent to develop similar methods that are already existing, and time can be saved.

One of the interviewed technical experts highlights that synergies effects can be deprived when having too many different software tools together with a lack of communication between simulation groups. A co-location of software resources can be beneficial and support synergies when all the used software to perform technical simulations are gathered and would also provide an overview of the resources. One of the purposes with the co-location of technical simulations and software is to share automated processes and structures between simulation groups. The possibility to develop new methods increases by the co-location.

6.2.1.2 Difficulties with Implementing Automated Processes

At Scania today, it exists a small number of automated processes, but they are steadily increasing. Four difficulties could be obstacles to obtain and support this increase. The first difficulty is the required time and resources that are needed to be put into the process to develop these methods of automated technical simulations. Time and resources would also be required in the development of the co-location of technical simulations as well as finding the right competencies to administer this formation. Another difficulty that could be seen is that the capability and trustworthiness in the models and the results that are delivered by the automated technical simulations need to be increased. This increase must happen to get reliable results that could serve as a base for further decision-making. The third difficulty and a challenge that needs to be handled to implement more automated technical simulations is the need for standardising and parametrise geometrical models. It is a work that is required by the design engineer and could simplify the process of inserting the model into the automated process. The last difficulty that could be seen is that today at Scania, information about the geometrical model is stored at several locations, making it difficult to find the value that is being searched for. This difficulty could potentially be solved by implementing MBD. MBD stores all the information in one place, supporting the need for a single source of information.

6.3 Development and Selection of Activities of Change

The suggested activities of changes were met with positivity from the focus company Scania. The activities were concrete and creative but somewhat radical. Some challenges with the implementation could be seen since the activities require major changes to the current process and organisation. It could also be seen, after the presentation of the found results, that the department of RT is currently aware of the challenges and difficulties that they are facing within the area. However, this master thesis confirms what they previously have had an idea about.

The chosen activities of change were found early in the analysis segment and have been refined together with co-workers at Scania, the steering committee and supervisors. An idea that was discarded was the extension of the current AD part of the yellow process type, which most likely would be easier to implement. Although compelling arguments for an orange arrow have been presented, such a change in Scania's overall model would affect the whole company. The reason for moving forward with the idea of an orange arrow is the simplification of applying different working methodologies and clearly specify the aim of each arrow. It was also done to present a more radical solution, clearly highlighting the fact that Scania is struggling with creating explorative space.

With the benchmarking, a generalising aspect could be retrieved with the study and the results confirmed the ongoing trend of digitalisation within the industry. However, since the activities of change is highly linked to Scania's current process and organisation it could be difficult to apply them directly to other companies. What on the other hand could be used are the overall ideas of handling the difficulties. There is an interest within several companies of increasing the implementation rate of both modern working methods and the use of technical simulations.

6.4 Additional Thoughts, Risks and Delimitations

Apart from the previously presented activities of change, a short discussion will be made concerning additional thoughts that have come up during the writing of this Master Thesis. Modular thinking will be discussed and potential risks with the chosen delimitations. The two delimitations that will be discussed is how the modern way of working should be handled and how the simulation trend could affect the results. There were difficulties when choosing delimitations within the area since it consists of several dimensions with interaction points. For example, the area of technical simulations relies on both design simulations as well as geometrical and embedded. The segment will end with a presentation of the shortcoming of the methodology.

6.4.1 Modular Thinking

The modular thinking impregnates the product development at Scania and has defined their final product for several years. Touched upon in the interviews, but not in focus, is how modular thinking is affecting the degree of innovation within the company. There are many dimensions to this idea, not all of them presented here, that could potentially be of interest to look further into to gain understanding about Scania's innovation process. For example, modular thinking could be of negative effect when exploring innovative solutions since the interface to the surroundings and requirements are set before starting the project. The modularity could also lead to an increase in lead time for concept development projects since several interfaces must be looked at. On the other hand, the modular thinking could potentially stimulate and speed up concept development, since the surrounding limitations are set early in the projects. Seen from the observation with the design engineer, modularisation was discussed, where the opinion was split considering the use of modular thinking. For a design engineer the modular thinking is time-consuming but, in the end, it is economic beneficial for Scania to use.

6.4.2 Handling the Symbiosis of Traditional and Modern Way of Working

Before performing the case study, it was set that the focus of the Master Thesis would be on the implementation of a modern way of working methodology and how the function of collaboration with technical simulations could be realized. Due to time limitations, the traditional way of working has therefore not been in focus but a short discussion of the symbiosis of the two should be performed. The two ways of working have their strengths and weaknesses and should, therefore, be applied to different situations. The output value must be put in relation to the needed effort to conduct the changes when moving from a traditional way of working to a more modern. The future, therefore, most likely holds a combination of the two ways of working and requires a complex transition phase.

6.4.3 Managing the Simulation Trend

The focus of this Master Thesis has been on the implementation of technical simulations in the modern way of working methodology. However, the simulation trend should be highlighted and critically reflected upon. As seen in several of the interviews, there is a need for increased speed, reduced lead time and some answers that the solution would be to implement simulation driven development within product concept development. It could also be seen that other producing companies are focusing on the implementation of technical simulations as well. The scope of this thesis focuses on handling the trend and implement it at Scania but there might be other solutions to solving the speed problem, for example conducting process changes. The implementation of technical simulations will face difficulties, seen in previous segments, such as scepticism from users, a problem with mimic the reality and knowledge for employees. These are just three examples of what needs to be solved.

6.4.4 Shortcoming of the Methodology

The chosen methodology was to use a case study together with a literature review and a minor benchmarking. The case study consisted of interviews, observations and a document study. The case study was chosen since it is applicable to the given task but what could be discussed is how optimal it is for technical research. The authors experienced that the focus could shift to sociology and that the technical aspect could be set aside. However, retrieved from literature there are not any other methodology that could better be suited for the aim of the thesis. The aim of the document study has shifted slightly during the process, from available support for co-workers in the yellow process, to simply understanding the yellow process. There were difficulties in retrieving the right documents, due to the access of documents were limited as well as knowing where to search for documents. Since Scania is a large company, the number of documents obstructed the opportunity to get a good overall understanding. The observations and the literature study were conducted as a complement to the case study and have therefore been performed to a limited extent until fullness was completed.

Due to time limitations, the benchmarking was conducted through surveys and the information retrieved was therefore limited. With an extended scope and more time resources, interviews would have been conducted. With interviews, it could have been controlled that the person answering was the right person for the aim of the study, the answers could have been elaborated and follow-up questions asked. However, even though shortcomings, the methodology was overall relevant and fulfilled the aim.

7. Conclusion

This segment of the report concludes and summarizes previous chapters by answering the stated research questions: R1, R2 and R3. Each research question is presented, and a short description follows, to fulfil the purpose of this Master Thesis.

7.1 Symbiosis Between Technical Simulations and Concept Development

The aim of the literature review, a part of the result, was to answer research question, R1:

R1 - How can a symbiosis between technical simulations and a modern way of working be implemented in explorative product concept development?

It was seen that the use of technical simulations within product concept development pushes the workload forward in the process, creating what is called a front-load. The front-loading will have several positive spin-off effects as well as difficulties, but technical simulations serve as a potential supporting resource tool when applying modern working methods. The supportive aspect comes from the fact that the tool could be used iteratively, handle continuous changes, provides a holistic approach as well as system thinking. Presented in literature are advantages and difficulties connected to the implementation as well as the usage of technical simulations within product concept development. These positive and negative aspects have been summarized and are presented in Table 7.1 and Table 7.2.

Table 7.1 Advantages of implementing technical simulations

Advantage	***Description***
Quality aspect	Improved quality of the products
Cost aspect	Reduced cost for the development of new products
Reduced lead time	Shortening of the total lead time from idea to customer
Sustainability aspect	Opportunities to assess and explore environmental decisions
Knowledge awareness	Reduced risks with understanding concerning product choices, delimitations and trade-offs
Advancement in AM	Complementing the technical simulations and gives the opportunity to explore and communicate different solutions

Table 7.2 Difficulties of implementing technical simulations

Phase were the difficulty could arise	***Difficulty***
Prior to implementation as well as during use	Knowledge for employees
Prior to implementation	Change of organizational structure
Prior to implementation	Scepticism from users
Prior to implementation	Implementing technical simulations early
During use	Mimic the reality
During use	Integration between software
During use	Restrictions in process power and supplier availability

7.2 The Usage of Technical Simulations

The performed case study consisted of a document study, interviews and observations, in combination with the benchmarking, to answer research question R2:

R2 – How are technical simulations utilised in concept development and what incentives effects the usage of technical simulations in early stages of modern concept development?

The first step to finding the answer to the given question was to map the current situation regarding concept development as well as technical simulations at Scania. It could be seen that the concept development takes place and is regulated by the yellow arrow. The yellow arrow is ended with the Concept Ready, was it is assessed if the project can be moved into green, industrialising, process type. There exists incitement of working with modern methodology within concept development, seen in "Rise of RT" but due to time restrictions and lack of resources, the methodology has not been implemented. However, other movements can be seen within different departments such as the use of sprints is being implemented.

The demand for performing a technical simulation is done by the design engineer, who uses a TA to send a request to the simulation groups. The simulation is performed, and the results are presented to the design engineer. The incitement for performing technical simulation relies on the setup of the current process as well as the design engineer and is highly project dependent. The interviewees' highlight that it is difficult to control the use of simulations since the role of the design engineers is individualistic and the process changes between projects. By creating a general understanding concerning the resource tool and its advantages, more technical simulations could be used, and rapid evaluation easier implemented in the concept development process.

The benchmarking acted as a complementing and generalizing dimension to the study and interesting results could be seen. Most companies have a formal description of the concept development process and several different software is being used within the process. The most common is that the technical simulations are being used to verify and investigate potential concept ideas. The decision-making concerning the technical simulations differs from company to company and a general setup cannot be seen. Factors that are affecting the use of technical simulations are for example the company tradition as well as the industry tradition, performance of the simulations and reliability. The companies in charge of delivering software solutions are seeing themselves as crucial and responsible to make interfaces and performance of the technical simulations sufficient.

7.3 Implementing Activities of Change

The last step was to perform an analysis of the answers to the previous research questions to answer research question R3:

R3 - What activities of change must be implemented to encourage modern explorative product concept development and simplify the use of technical simulations?

The suggested activities of change to Scania are divided into two focus areas: process and organisation. Since difficulties were found within the process concerning the lack of explorative space, unclear definition of a concept as well as a too slow process, changes must be made. The suggested changes that are necessary to perform is the implementation of an orange process at Scania as well as starting to use digital demonstrators as a concept definition. By having two different processes, one orange and one yellow, resources can be liberated for exploratory projects, the aim of each arrow can clearly be stated and an adapted working methodology can be implemented. An illustration of the processes can be seen in Figure 7.1

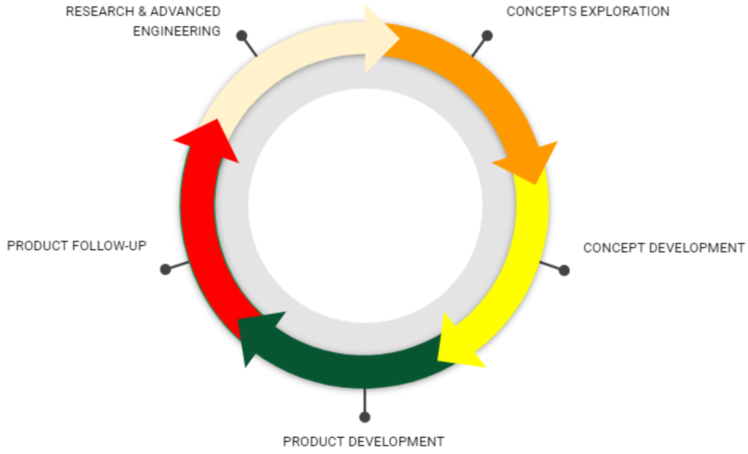


Figure 7.1 Suggested new approach to the process of concept development

The implementation of using digital demonstrators as concept definitions would be in line with the digitalisation of the industry and three major advantages can be seen. The degree of innovation would increase since several solutions can be investigated simultaneously, it simplifies building functional models and it answers the stated need from the customer.

The second area were activities of change need to be applied, is within the current organisation at Scania. The design engineer has a crucial role concerning the use of technical simulations, and by reworking the role of the design engineer, the frequency of performing different tasks can be increased and bigger confidence created. A split will be created, giving one strategic and one operative design engineer. The second organisational change that would need to be implemented is the idea of the layer structure, seen in Figure 7.2.

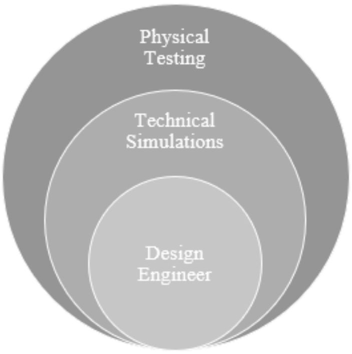


Figure 7.2 Layer structure of how TA will be assigned to encourage a greater collaboration

The structure would increase communication, collaboration, and understanding between the three parts: design, simulation, and test engineer. The final suggested activity would be to improve the network with other companies at the forefront of simulation-driven development since it can act as both knowledge-building as well as providing support.

With the retrieved results, this Master Thesis has answered the purpose and accomplished the aim, created methodology prerequisites and encouragement for modern working methods supported by technical simulations, to potentially improve exploration.

8. Further Studies

Presented here are the recommendations for future work. The authors have experienced and encountered interesting aspects during the writing of this master thesis but could not investigate them all due to limitations, this segment gives a chance to continue the development.

8.1 Recommendations for future work

Gathered and collected during the authors time at Scania are interesting thoughts on further studies within the subject of modern product concept development and technical simulations. The ideas and a short description are presented in Table 8.1.

Table 8.1 Suggested further studies within the subject

Idea	*Short description*
Number of projects running concepts parallel in yellow arrow	Find a way of measuring the degree of innovation in Scania's previously performed yellow projects
Definition of a concept	Look further into what is defining a concept and what can be classified as a new concept. Needs to be done to perform the suggested study above
Compare yellow and green arrow in relation to technical simulation	Should different processes in relation to technical simulations be implemented in yellow and green projects?
Sprint-based methodology	Investigate the potential of implementing more sprints and the option of having design and simulation engineers in the same sprints
GAP analysis of strategy and reality	RT technical simulation strategy and the current situation at each group could potentially show improvements on how to reach out and implementing more simulations
Validation of technical simulations by physical testing	Investigate how recurrent physical test can validate simulations, due to when the request comes again it could be performed digitally instead

Gathered and collected during the authors time at Scania are interesting thoughts on further studies within neighbouring subjects. The ideas and a short description are presented in Table 8.2.

Table 8.2 Suggested further studies within neighbouring subjects

Idea	*Short description*
Investigate the relation between traditional and modern ways of working	Investigate which areas within Scania that could benefit from a traditional way of working as well as areas were modern changes would be optimal.
Design for Analysis in relation to the design engineers	Explore the potential of implementing Design for Analysis for the design engineers in an early stage. Design for Analysis aims to only focus on designs that can be analysed with simple tools quickly and easy.
External suppliers and Scania's role in implementing MBD	Look into how the current situation of Scania's suppliers concerning MBD is and investigate if there is a potential barrier.
Implementation of MBD in relation to production	Look into the current relation of Scania's production and MBD, in addition to investigate the potential of full implementation of MBD
Investigate the relation between mechanical and system development	Evaluate the present situation of the collaboration between systems and mechanics, investigate what is needed to enable technical simulations together with virtual trucks to create a fully integrated vehicle

Bibliography

Agile Business Consortium Limited. (2019). Handbook MoSCoW Prioritisation. Retrieved April 3, 2019, from https://www.Agilebusiness.org/content/moscow-prioritisation

Ahlgren, H. & Landström, M. (2017). Success within Frond End of Innovation (Master Thesis, Department of Mechanical Engineering, Institution of Industrial Engineering and Management, Royal Institute of Technology, Stockholm, Sweden).

Ahrne, G & Svensson, P. (2015). *Handbok i kvalitativa metoder* (pp.93–113). Stockholm, Sverige: Liber.

American Psychological Association. (2017). Ethical Principles of Psychologist and Code of Conduct. Retrieved March 6, 2019, from https://www.apa.org/ethics/code

Andreasen, M.M., Hansen, C.T. & Cash, P. (2015). Introductions: Conceptualization. *Conceptual Design. Interpretations, Mindset and Models.* (p.1-4) Basel, Switzerland: Springer.

Assa Abloy. (2019). Världsledande inom lås- och dörrlösningar. Retrieved March 27, 2019, from https://www.assaabloy.se/sv/country/se/om-assa-abloy/

Banfield, R. (2019). Enterprise Design Sprints. Retrieved April 4, 2019, from https://www.designbetter.co/enterprise-design-sprints/design-sprints-enterprises

Beck, K., Beedle M., van Bennekum A., Cockburn A., Fowler M., Grenning J., Highsmith J., Hunt A., Jeffries R., Kern J., Marick B., Martin R., Mellor S., Schwaber K., Sutherland J. & Thomas D. (2001). *Manifesto for Agile Software Development*. Retrieved April 3, 2019, from http://Agilemanifesto.org/

Benington, H. (1983). Production of Large Computer Programs. *IEEE Educational Activities Department*. 5 (4): 350–361. Retrieved April 11, 2019, from http://10.1109/MAHC.1983.10102.

Bergström, F. & Björkvall, M. (2015). *Simulation Based product development and Competitiveness* (Master Thesis, Quality Technology and Management Division, Department of Management and Engineering, Linköping University, Sweden).

Bjärnemo. R., Burman, A. & Anker, J.C. (1993). FEA in the Engineering Design Process. *Control and Dynamics Systems*, VOL. 58.

Bombardier. (2019). About us. Retrieved March 27, 2019, from https://www.bombardier.com/en/about-us.html

British Design Council. (2016). Eleven lessons. A study of the design process. Retrieved June 4, 2019, from www.designcouncil.org.uk

Brown, T. & Kätz, B. (2009). *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation.* New York, United States of America: Harper Business.

CA Technologies. (2019, June 7). The Difference Between Lean and Agile [video file]. Retrieved May 9, 2019, from www.youtube.com/watch?v=aUd3xTdtXqI

Cooper, R.G. (2016) Agile-Stage-Gate Hybrids – The Next Stage for product development. *Research-Technology Management*. 59(1), (pp.21-29) https://doi.org/10.1080/08956308.2016.1117317

Cooper, R.G & Friis Sommer, A. (2018) Agile-Stage-Gate for Manufacturers – Changing the Way New Products Are Developed. *Research-Technology Management*. 61(2), (pp.17-26). Retrieved April 3, 2019, from https://doi.org/10.1080/08956308.2018.1421380

Dagnino. G. B. & Cinici, M.C. (2016). *Research Methods for Strategic Management* (p.4-5). New York, NY: Routledge.

Dam, R. & Siang, D. (2018). 5 Stages in the Design Thinking Process. *Interaction Design Foundation*. Retrieved February 27, 2019, from https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process

Denning, S. (2011). *Innovation: Applying "Inspect & Adapt" To the Agile Manifesto*. Retrieved April 3, 2019, from http://www.forbes.com/sites/stevedenning/2011/05/04/innovation-applying-inspect-adapt-to-the-Agile-manifesto/#150960361804. innovation-applying-inspect-adapt-to-the-Agile-manifesto/\#150960361804

Dereli, D.D. (2015). Innovation Management in Global Competition and Competitive Advantage. *Procedia - Social and Behavioural Sciences* 195 (2015) 1365 – 1370 Retrieved March 19, 2019, from https://ac-els-cdn-com.ludwig.lub.lu.se/S1877042815038021/1-s2.0-S1877042815038021-main.pdf?_tid=cc8d7044-bff8-49a5-947d b33b24274742&acdnat=1552999632_925c84b79372669eb2a3fbd51937e2e4

Design Council. (2019). The Design Process: What is the double diamond? Retrieved May 8, 2019, from https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond

Design Spring Academy. (2019). About Design Sprint 3.0. Retrieved March 13, 2019, from https://designsprint.academy/design-sprint-3-0/

DSDM Consortium (2019) *What is DSDM?* Retrieved April 3, 2019, from https://www.Agilebusiness.org/what-is-dsdm

Eriksson, M. & Motte, D. (2013). Investigation of the Exogenous Factors Affecting the Design Analysis Process. International Conference of Engineering Design ICED13. Seoul, Korea: Sungkyunkwan University

Femto Engineering. (2019). [Quick introduction to Topology Optimization] Retrieved March 21, 2019, from https://www.femto.eu/stories/topology-optimization/

Function Bay. (2014). [Why CAE Simulation? Multi Body Dynamic software, Numerical Simulation or Flexible Multi Body Dynamics software?] Retrieved March 20, 2019, from http://www.functionbay.de/why-multibody- dynamics-simulation.html

Geissbauer, R, Schrauf, S & Morr, J.T. (2019). *Digital product development 2025 – Agile, Collaborative, AI Driven and Customer Centric.* PWC – PricewaterhouseCoopers GmbH Wirtschaftprüfungsgesellschaft, Berlin, Germany

Goffin, K. & Mitchell, R. (2017). Generating Innovative Ideas. *Innovation Management, Effective Strategy and Implementation.* (p. 194) London, Great Britain: Palgrave.

Hadley, E. (2017). Design Thinking vs. Agile: Combine Problem Finding and Problem Solving for Better Outcome. Retrieved February 2, 2019, from https://www.mendix.com/blog/design-thinking-vs-Agile-combine-problem-finding-problem-solving-better-outcomes/

Haldex. (2019). About Haldex. Retrieved March 27, 2019, from http://corporate.haldex.com/en/abouthaldex

Hallberg, P. (2012) *Low-Cost Demonstrators Enhancing product development with the Use of Physical Representations.* (PhD Thesis, Division of Machine Design, Department of Management & Engineering) Linköping University, Faculty of Science and Engineering, Linköping, Sweden

Hallin, A & Helin, J. (2018). *Intervjuer* (pp.31–40). Lund, Sweden: Studentlitteratur.

Hohl, P., Klünder, J., van Bennekum, A., Lockard, R., Gifford, J., Münch, J., Stupperich, M. & Schneider, K. (2018). Back to the future: origins and directions of the "Agile Manifesto" – views of the originators. Journal of Software Engineering Research and Development. 2018 6:15. Retrieved April 3, 2019, from https://doi.org/10.1186/s40411-018-0059-z

Ingle, B.R. (2013). Introduction to Design Thinking. *Design Thinking for Entrepreneurs and Small Businesses: Putting the Power of Design to Work.* (p.1-15). New York, NY: Springer.

Ishiyama, J.T & Breuning, M. (2011). *21st Century Political Science – A reference Handbook* (pp.490-498) Thousand Oaks, SAGE Publications Inc.

Jaghbeer, Y, Hallstedt, S.I, Larsson, T & Wall, J. (2017). Exploration of simulation-driven support tools for sustainable product development. *The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems*. (pp.271-276). Blekinge Institute of Technology, Karlskrona, Sweden.

Johansson, K., Senior Technical Advisor – Simulations at Scania, Södertälje, Sweden. Personal conversation (2019, 22 February).

Johansson, K. (2018). Simulation Based product development [PowerPoint slides]. RTA, Scania, Södertälje, Sweden.

Johansson, S & Sätterman, D. (2012). *Simulation Driven product development - How it can be combined with Lean Philosophy to achieve increased product development efficiency*. (Master Thesis, Department of Production Engineering KTH Royal Institute of Technology, Stockholm, Sweden)

Karlsson, M. & Vesterlund, C. (2018). *Managing the Innovation Paradox of Exploitation and Exploration in R&D* (Master Thesis, Division of Industrial Management, Department of Mechanical Engineering, KTH Royal Institute of Technology, Stockholm, Sweden).

Karningsiha, P.D., Anggrahinib, D. & Syafi'i, M. I. (2015). Concurrent engineering implementation assessment: A case study in an Indonesian manufacturing company. *Procedia Manufacturing* 4 (2015) 200 – 207. Retrieved March 25, 2019, from 10.1016/j.promfg.2015.11.032

Karlöf, B. (2009). *Benchmarking – med lärande för att utveckla företag, organisationer och människor.* (pp.90-105). Malmö, Sweden: Liber.

Keinonen, T. & Takala, R. (2006) Preface. *Product Concept Design* (p.6) London, Great Britain: Springer.

Khalil, A. & Kotaiah, B. (2017). Implementation of Agile Methodology based on SCRUM tool. 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS). Retrieved 3 April, 2019, from http://10.1109/ICECDS.2017.8389872

Kianian, B, Tavassoli, S, Larsson, T.C., & Diegel, O. (2016) The Adoption of Additive Manufacturing Technology in Sweden. *13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use*. (pp.7-12). Ho Chi Minh City/ Binh Duong, Vietnam: Elsevier

King, G.S., Jones, R.P & Simmer, D. (2003). *A good practice model for implementation of computer-aided engineering analysis in product development.* Journal of Engineering Design, Vol 14, 315-331.

Komatsu Forest. (2019). Forestry Quality. Retrieved March 27, 2019, from https://www.komatsuforest.se/om-oss

Krause, F-L. (2007). *The future of product development* (pp.10-11, 595-616). Berlin, Germany: Springer Verlag Berlin Heidelberg.

Kretzschmar, N. & Chekurov, S. (2018). The Applicability of the 40 TRIZ Principles in Design for Additive Manufacturing. *Proceedings of the 29th DsAAAM International Symposium*, pp.0888-0893, B. Katalinic (Ed.). Retrieved February 27, 2019, from 10.2507/29th.daaam.proceedings.128

Krotil, S & Reinhart, G. (2016). CFD-Simulations in The Early product development. *13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use.* (pp.443-448) Augsburg, Germany: Elsevier

Kvale, S & Brinkmann, S. (2014). *Den kvalitativa forskningsintervjun* (pp.141–164, pp.172–179, 206). Lund, Sweden: Studentlitteratur.

Lagaros, N.D. (2018). The environmental and economic impact of structural optimization. *Structural and Multidisciplinary Optimization* (2018) 58:1751–1768. Retrieved February 27, 2019, from https://doi.org/10.1007/s00158-018-1998-z

Lantz, A. (2013). *Intervjumetodik* (pp.41–62, 77–78) Lund, Sweden: Studentlitteratur.

Li, Y., Wang, J., Li, X. & Zhao, W. (2007). Design creativity in product innovation. *Int J Adv Manuf Technol* (2007) 33: 213–222. Retrieved March 25, 2019, from https://rd.springer.com/article/10.1007/s00170-006-0457-y

Lindsten, P-O. (2018). Här är Sveriges största företag 2018. *Veckans Affärer.* Retrieved February 21, 2019, from https://www.va.se/nyheter/2018/11/29/VA500-2018-insights/

Lund, K & Tingström, J. (2011). Facilitating Creative Problem Solving Workshops: Empirical Observations at a Swedish Automotive Company. *International Conference on Engineering Design, ICED11* (pp.275-284). Lungby/Copenhagen, Denmark: Human Behaviour in Design

Marr, B. (2018). What is Industry 4.0? Here's A Super Easy Explanation for Everyone. *Forbes*. Retrieved February 27, 2019, from https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#58fb73b49788

McDonough, J. & McDonough, S. (1997). Research Methods for English Language Teachers. London, Great Britain: Arnold.

McKenna, D. (2016). The Agile Principles. *The Art of Scrum: How Scrum Masters Bind Dev Teams and Unleash Agility*. (pp. 18-25) Aliquippa, Pennsylvania: CA Technologies.

Mind Tools Content Team. (2019, February 25). How to Use Timeboxing [video file]. Retrieved April 3, 2019, from https://www.youtube.com/watch?time_continue=28&v=GbqdFH18m2g

Morris, L., Ma, M. & Wu, P.C. (2014). Managing Innovation for Tomorrow. *Agile Innovation: The Revolutionary Approach to Accelerate Success, Inspire Engagement, and Ignite Creativity* (p.71-72) Hoboken, New Jersey: John Wiley & Sons Inc

Mullins, J.W. & Sutherland, D.J. (1998). New product development in Rapid Changing Markets: An Exploratory Study. *J PROD INNOV MANAG* 1998; 15:224-236.

Myers, S. & Marquis, D.G. (1969). *Successful industrial innovations. A study of factors underlying innovation in selected firms*. Washington: National Science Foundation.

Naylor, J., Naim, M. & Berry, D. (1999). Legality: Integrating the lean and Agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics*, Volume 62, Issues 1–2. Retrieved May 9, 2019, from https://doi-org.ludwig.lub.lu.se/10.1016/S0925-5273(98)00223-0

Nerur, S. & Balijepally, V. (2007). Theoretical Reflections on AGILE DEVELOPMENT METHODOLOGIES. *COMMUNICATIONS OF THE ACM*, March 2007/Vol. 50, No.3.

Nessler, D. (2016). How to rethink the Design process, fail, reflect and iterate. Retrieved May 8, 2019, from https://uxdesign.cc/how-to-fuck-up-the-design-thinking-process-and-make-it-right-dc2cb7a00dca

Nicol, A. (2011). Model and Simulate, Or Prototype and Test: Which Is Best? Retrieved March 26, 2019, from https://www.manufacturing.net/article/2011/12/model-and-simulate-or-prototype-and-test-which-best

Pessõa, M.V.P. & Trabasso, L.G. (2017). *The Lean Product Design and Development Journey*. (pp.43-53). São Paulo Brazil: Springer.

Petersson, H. (2016). *Template Base Design Analysis – An alternative Approach for Engineering Designer to Perform Computer-Based Design Analysis* (PhD Thesis, Department of Design Sciences LTH, Lund University, Lund, Sweden).

Petrén, O. Head of Modularisation (YDMM) at Scania, Södertälje, Sweden. Interview (2019a, 20 March)

Petrén, O. (2019b, 15 March). concept development. Retrieved April 10, 2019, from https://internal.sca nia.com/pdprocess/126.html

Petrén, O. (2018). Yellow Arrow Process [PowerPoint slides]. YDM, Scania CV AB. Södertälje, Sweden

Pocketsmith. (2019). What-if scenarios. Retrieved April 5, 2019, from https://www.pocketsmith.com/tour/what-if-scenarios

PowerSlides. (2019). Agile Scrum Processes. Retrieved April 3, 2019, from https://www.powerslides.com/powerpoint-business/project-management-templates/Agile-scrum-process/

Project Management Knowledge. (2019). *Facilitated Workshops.* Retrieved April 3, 2019, from https://project-management-knowledge.com/definitions/f/facilitated-workshops/

Quintana, V., Rivest, L., Pellerin, R., Venne, F. & Kheddouci, F. (2010). Will Model-based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry. *Computers in Industry* 61 (2010) 497–508.

Roth, G. (1999). *Analysis in Action: The Value of Early Analysis*. Canonburg, PA: ANSYS

Ruemler, S., Zimmerman, E., Hartman, N., Hedberg, T. & Feeny, A. (2018). Promoting Model-based Definition to Establish a Complete Product Definition. *J Manuf Sci Eng*. Retrieved April 10, 2019, from https://10.1115/1.4034625

Russell, S. J. and Norvig, P. (2010). *Artificial Intelligence: A Modern Approach.* 3rd ed. Harlow, United Kingdom: Pearson Education Limited.

SAAB Aeronautics. (2019). Aeronautics. Retrieved March 27, 2019, from https://saabgroup.com/about-company/organization/business-areas/

Scania. (2019a). [Homepage About Us for Scania]. Retrieved February 21, 2019, from https://www.scania.com/se/sv/home/experience-scania/about-us.html

Scania. (2019b). [Homepage Innovation Boosting Uptime] Retrieved February 21, 2019, from https://www.scania.com/se/sv/home/experience-scania/features/innovation-boosting-uptime.html

Schoggl, J-P., Baumgartner, R.J. & Hofer, D. (2017). Improving sustainability performance in early phases of product design: A checklist for sustainable product development tested in the automotive industry. *Journal of Cleaner Production* 140 (2017) 1602-1617

Shephard, M.S., Beall, M.W., O'Bara, R.M., & Webser, B.E. (2003). *Toward simulation-based design.* Scientific Computation Research Centre, Rensselaer Polytechnic Institute, Troy, NY

Simmetrix, Inc., 10 Halfmoon Executive Park Drive, Clifton Park, NY 12065

Skarzynski, P. (2008). *Innovation to the core* (pp.4-8). Boston, MA: Harvard Business School Press.

SKF. (2019). About us. Retrieved March 27, 2019, from https://www.skf.com/us/our-company/index.html

Siemens. (2019). Digital mock-up and high-performance visualization to unleash designs. Retrieved April 11, 2019, from https://www.plm.automation.siemens.com/global/en/ products/collaboration/digital-mockup.html

Srivastava, A., Bhardwaj, S. & Saraswat, S. (2017). SCRUM model for Agile Methodology. 2017 *International Conference on Computing, Communication and Automation* (ICCCA). Retrieved April 3, 2019, from http:// 10.1109/CCAA.2017.8229928

Sunner, D. (2016). Agile: Adapting to need of the hour: Understanding Agile methodology and Agile techniques. 2016 2nd *International Conference on Applied and Theoretical Computing and Communication Technology* (iCATccT). Retrieved April 3, 2019, from http://10.1109/ICATCCT.2016.7911978

Swedish Research Council. (2017). Good Research Practise. Retrieved March 11, 2019, from https://www.vr.se/download/18.5639980c162791bbfe697882/1529480529472/Good-Research-Practice_VR_2017.pdf

Thiel, T. (2019). Agilt arbete på RT, byggt på underlaget från förbättringsarbetet RISE of RT [PowerPoint slides]. RTA, Scania, Södertälje, Sweden.

Thomke, S. (1998). Simulation, learning and R&D performance: evidence from automotive Development. *Research Policy*, Vol. 27 No. 1, pp. 55-74. Retrieved March 26, 2019, from https://doi-org.ludwig.lub.lu.se/10.1016/S0048-7333(98)00024-9

Trott, P. (2017). *Innovation Management and New product development* (pp.15). Edinburgh, United Kingdom: Pearson Education.

Virtual Nation. (2014). *Strategisk forsknings- och innovationsagenda inom simulering för perioden 2014–2030.* Svensk kraftsamling kring numerisk simulering.

Wikström, J., Object Manager at Scania, Södertälje, Sweden. Interview (2019, 1 April)

Yin, R.K. (2018). *Case study research and applications: design and methods* (pp.5-47). Thousand Oaks: Sage Publications.

Yin, R.K. (2016). *Qualitative Research from start to finish* (pp.142-143). New York: Guilford Publications.

Zainal, Z. (2007). Case study as a research method. *Jurnal Kemanusiaan* bil.9, June 2007.

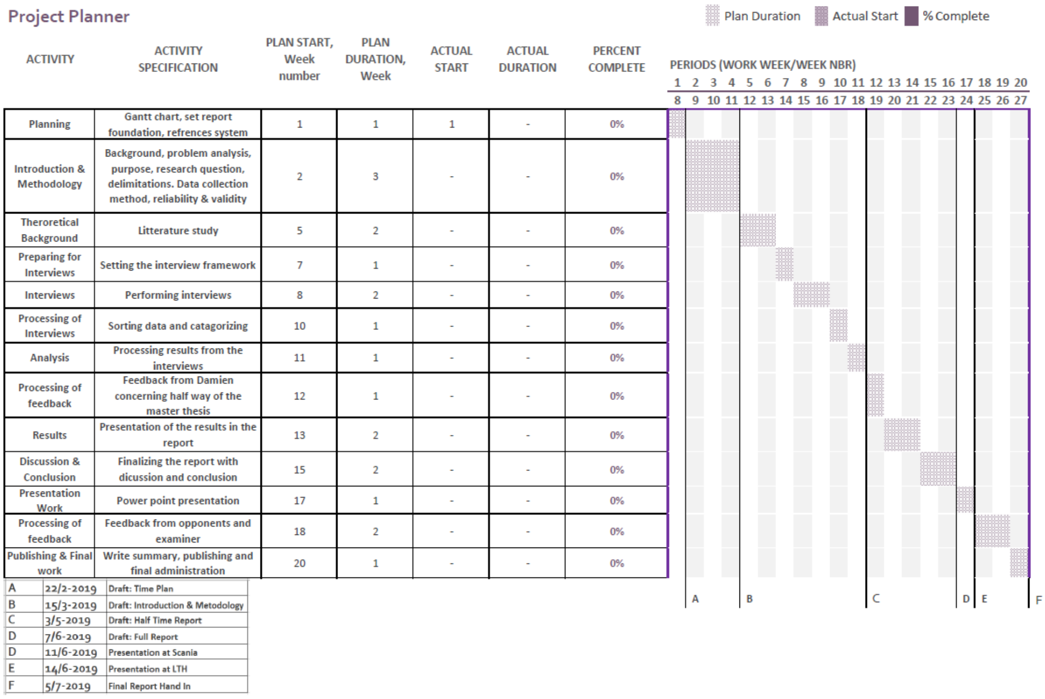
Zapf, J., Alber-Laukant, B. & Rieg, F. (2011). Usability Compliant Supportive Technologies in Simulation-Driven Engineering. *International Conference on Engineering Design, ICED11*. (pp.1-8). Copenhagen, Denmark: ICED.

Zipperer, L. & Amori, G. (2011). Knowledge management: An innovative risk management strategy. Journal of healthcare risk management 30(4). Retrieved March 26, 2019, from https://onlinelibrary-wiley-com.ludwig.lub.lu.se/doi/epdf/10.1002/jhrm.20064

Özaksel, G. (2008). Kvalitetsbristkostnader som begrepp och instrument för att reducera företagets slöserier. *Swerea* IVF-rapport 09001, ISSN 1404-191X. Retrieved March 26, 2019, from https://www.swerea.se/sites/default/files/publications/swereaivf-rapport_09001_rev1.pdf

Appendix A – Plan for Master Thesis

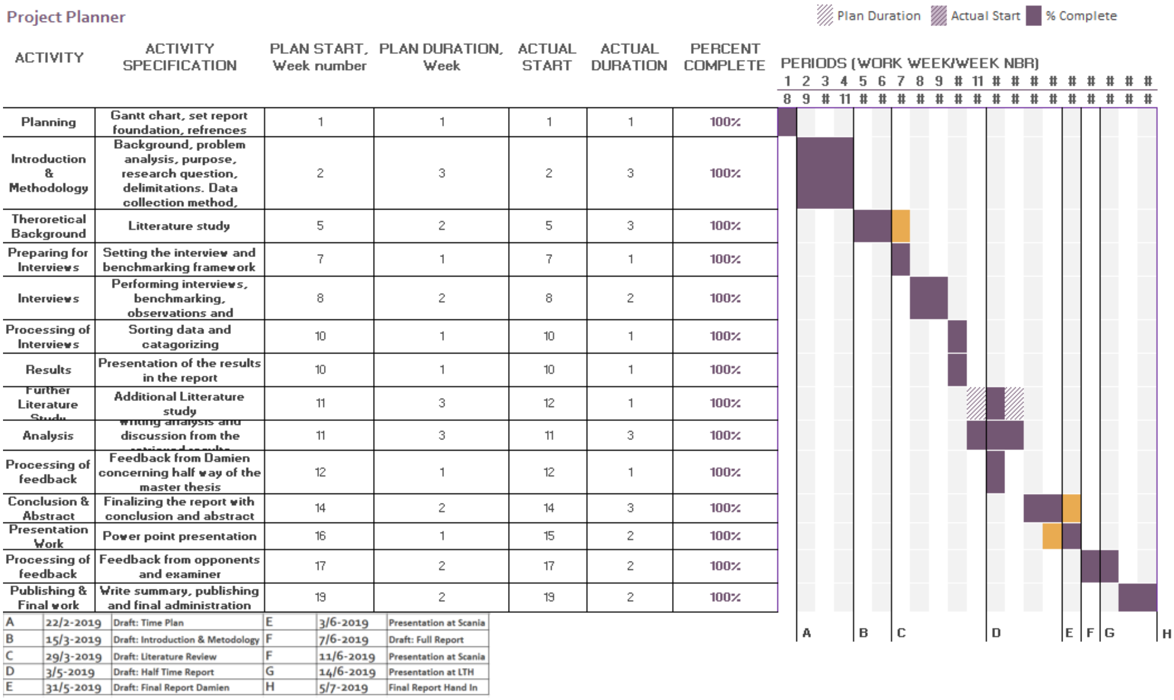
Presented are the actual time plan, seen in Figure A.1, and the outcome, seen in Figure A.2.



ACTIVITY	ACTIVITY SPECIFICATION	PLAN START, Week number	PLAN DURATION, Week	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Planning	Gantt chart, set report foundation, refrences system	1	1	1	-	0%
Introduction & Methodology	Background, problem analysis, purpose, research question, delimitations. Data collection method, reliability & validity	2	3	-	-	0%
Theroretical Background	Litterature study	5	2	-	-	0%
Preparing for Interviews	Setting the interview framework	7	1	-	-	0%
Interviews	Performing interviews	8	2	-	-	0%
Processing of Interviews	Sorting data and catagorizing	10	1	-	-	0%
Analysis	Processing results from the interviews	11	1	-	-	0%
Processing of feedback	Feedback from Damien concerning half way of the master thesis	12	1	-	-	0%
Results	Presentation of the results in the report	13	2	-	-	0%
Discussion & Conclusion	Finalizing the report with dicussion and conclusion	15	2	-	-	0%
Presentation Work	Power point presentation	17	1	-	-	0%
Processing of feedback	Feedback from opponents and examiner	18	2	-	-	0%
Publishing & Final work	Write summary, publishing and final administration	20	1	-	-	0%

A	22/2-2019	Draft: Time Plan
B	15/3-2019	Draft: Introduction & Metodology
C	3/5-2019	Draft: Half Time Report
D	7/6-2019	Draft: Full Report
D	11/6-2019	Presentation at Scania
E	14/6-2019	Presentation at LTH
F	5/7-2019	Final Report Hand In

Figure A.1 Time plan set prior to starting



ACTIVITY	ACTIVITY SPECIFICATION	PLAN START, Week number	PLAN DURATION, Week	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Planning	Gantt chart, set report foundation, refrences	1	1	1	1	100%
Introduction & Methodology	Background, problem analysis, purpose, research question, delimitations. Data collection method,	2	3	2	3	100%
Theroretical Background	Litterature study	5	2	5	3	100%
Preparing for Interviews	Setting the interview and benchmarking framework	7	1	7	1	100%
Interviews	Performing interviews, benchmarking, observations and	8	2	8	2	100%
Processing of Interviews	Sorting data and catagorizing	10	1	10	1	100%
Results	Presentation of the results in the report	10	1	10	1	100%
Further Literature Study	Additional Litterature study	11	3	12	1	100%
Analysis	writing analysis and discussion from the retrieved results	11	3	11	3	100%
Processing of feedback	Feedback from Damien concerning half way of the master thesis	12	1	12	1	100%
Conclusion & Abstract	Finalizing the report with conclusion and abstract	14	2	14	3	100%
Presentation Work	Power point presentation	16	1	15	2	100%
Processing of feedback	Feedback from opponents and examiner	17	2	17	2	100%
Publishing & Final work	Write summary, publishing and final administration	19	2	19	2	100%

A	22/2-2019	Draft: Time Plan	E	3/6-2019	Presentation at Scania
B	15/3-2019	Draft: Introduction & Metodology	F	7/6-2019	Draft: Full Report
C	29/3-2019	Draft: Literature Review	F	11/6-2019	Presentation at Scania
D	3/5-2019	Draft: Half Time Report	G	14/6-2019	Presentation at LTH
E	31/5-2019	Draft: Final Report Damien	H	5/7-2019	Final Report Hand In

Figure A.2 Actual time plan of the performed Master Thesis

Appendix B – Interview Guide Section Manager

B1. Introduktion

Vad anser du att din nuvarande tjänst som sektionschef på RXX innebär?

Hur och i vilken utsträckning anser du att ditt arbete relaterar till konceptutveckling för produkter?

B2. Konceptutveckling och exploration

Hur skulle du beskriva att Scania arbetar med konceptutveckling idag?

Om du skulle uppskatta hur lång tid ett konceptutvecklingsprojekt tar, inom vilken tidsram genomförs de flest projekten?

Hur skulle du definiera Koncept Klart?

Vilka trender upplever du finns inom konceptutveckling? Vilka trender behöver Scania ta hänsyn till?

Hur skulle du definiera ett modernt arbetssätt inom konceptutveckling för produkter?

B3. Tekniska simuleringar och konceptutveckling

Hur används tekniska simuleringar i den gula fasen, konceptutveckling?

Används de olika programvarorna jämt fördelat över tiden eller är det mer intensivt i vissa skeden?

Hur många personer är det i genomsnitt som arbetar med tekniska simuleringar under en konceputvecklingsfas?

Vilka är det som genomför de tekniska simuleringarna?

Hur många konstruktörer/beräkningsingenjörer arbetar på din grupp?

Finns det någon anledning till vald uppdelning mellan konstruktörer och beräkningsingenjörer?

Vilken utbildning internt får de som ska arbeta med tekniska simuleringar?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar i en tidig konceptutveckling?

B4. Tekniska simuleringar och modern konceptutveckling

Vi pratade tidigare om trender inom konceptutveckling och moderna arbetssätt. Hur tror du att användandet av tekniska simuleringar skulle kunna stötta eller försvåra detta arbetssätt?

Appendix C – Interview Guide Simulation Engineers

C1. Introduktion

Hur och i vilken utsträckning anser du att ditt arbete relaterar till konceptutveckling för produkter?

Tror du att sättet man arbetar med konceptutveckling idag på Scania behöver ändras?

C2. Tekniska simuleringar

Vad skulle du säga är den vanligaste programvaran som används inom din gruppering är idag?

Hur många olika programvaror är det som används?

Vilka simuleringar gör konstruktören och vilka för beräkningsingenjören?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar?

De enklaste simuleringarna görs av konstruktörer, när övergår simuleringarna att göras av beräkningsingenjörerna?

Hur skiljer sig tidsåtgången?

Vad är upplägget när ni får ett uppdrag? Från första kontakt till slutresultat?

Hur är arbetsbelastningen på din grupp? Hur lång tid kan en förfrågan behöva vänta?

Finns det något samarbete mellan konstruktör och beräkningsingenjör när det gäller körning av simuleringar?

C3. Tekniska simuleringar och konceptutveckling

Hur används tekniska simuleringar i den gula fasen, konceptutveckling?

Hur många personer är det i genomsnitt som arbetar med tekniska simuleringar under en konceputvecklingsfas?

I ett gult projekt, hur mycket tid läggs uppskattningsvis på tekniska simuleringar?

Är det skillnad på tidsåtgången för simuleringar i ett gult eller grönt projekt?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar i en tidig konceptutveckling?

Appendix D – Interview Guide Design Engineers

D1. Introduktion

Vilka arbetsuppgifter har man som konstruktör? Vad ingår i det dagliga arbetet?

Hur och i vilken utsträckning relaterar ditt arbete till konceptutveckling för produkter?

Tror du att sättet man arbetar med konceptutveckling idag på Scania behöver ändras?

D2. Tekniska simuleringar

Vad skulle du säga är de vanligaste programvarorna som används inom din gruppering är idag?

Vilka simuleringar kan konstruktören göra?

Vilka simuleringar gör beräkningsingenjören?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar i konstruktörernas arbete?

När används simuleringar i konstruktörens arbete?

När övergår simuleringarna att göras av beräkningsingenjörerna?

Vad är upplägget när ni önskar göra simuleringar? Från start till slutresultat?

Hur är arbetsbelastningen på din grupp?

Finns det något samarbete mellan konstruktör och beräkningsingenjör i dagens läge?

Tekniska simuleringar och konceptutveckling

Har du suttit med i ett gult projekt?

Hur används tekniska simuleringar i den gula fasen, konceptutveckling?

Används simuleringar jämt fördelat över tiden eller är det mer intensivt i vissa skeden?

I ett gult projekt, hur mycket tid läggs uppskattningsvis på tekniska simuleringar?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar i en tidig konceptutveckling?

Appendix E – Interview Guide External Informant

E1. Introduction

What is your background?

How long have you been a consultant at Scania?

Could you describe your current position you have today?

What is a sprint coordinator?

E2. Sprint & Agile

Could you briefly describe what a simulation sprint is and its advantages and challenges?

Why was there a need of simulation sprints?

What needs to be considered when implementing simulation sprints?

How does it work with sprints in yellow and green process type?

Does your work relate to concept development and yellow process type at Scania today?

If yes, how does the process work according to your opinion?

How long are the sprints?

How to think when milestones are set?

When sprints were introduced, how was the reaction?

E3. Administration concerning simulation sprints

Meetings, how many?

Evaluation matrix? How is the evaluation performed?

E4. Future

What changes do you think have to be implemented at Scania to keep up with future challenges?

Appendix F – Survey Questionnaire Production Companies

F1. Konceptutveckling

I vilken utsträckning anser du att ditt arbete relaterar till konceptutveckling för produkter?

Finns det någon formaliserad beskrivning av den process ni tillämpar i konceptsutvecklingsarbetet?

Finns det någon skillnad vad gäller traditionella utvecklingsprojekt och mer explorativa i tillvägagångssätt under konceptstadiet? Vad är skillnaden? Är det skillnad i tidsåtgång mellan dem?

Tror du sättet man arbetar med konceptutveckling idag behöver ändras? Varför/varför inte?

Vilka trender upplever du finns inom konceptutveckling?

Hur skulle du definiera ett modernt arbetssätt inom konceptutveckling för produkter?

F2. Tekniska Simuleringar

Vad skulle du säga är den vanligaste programvaran som används på företaget och hur många olika programvaror används?

Vilka tekniska simuleringar gör konstruktören respektive beräkningsingenjören?

Vilken utbildning internt får de som ska arbeta med tekniska simuleringar?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar, vad uppmuntrar användandet och vilka svårigheter finns det?

Var sker beslutsfattande kring processer och tekniska simuleringar samt mjukvara?

F3. Tekniska simuleringar och konceptutveckling

Hur används tekniska simuleringar i konceptutveckling?

Hur många personer är det i genomsnitt som arbetar med tekniska simuleringar under en konceputvecklingsfas och används tekniska simuleringar över tiden i konceptutvecklingen?

Vilka faktorer påverkar användandet av tekniska simuleringar i konceptutvecklingen, vad uppmuntrar och vilka svårigheter finns det?

Hur tror du att användandet av tekniska simuleringar skulle kunna stötta ett modernt arbetssätt?

Tror du att användandet av tekniska simuleringar kan försvåra utvecklingen av ett modernt arbetssätt, varför/varför inte?

Appendix G – Survey Questionnaire Software Companies

G1. Konceptutveckling

Hur och i vilken utsträckning anser du att ditt arbete relaterar till konceptutveckling för produkter?

Vilka trender upplever du finns inom konceptutveckling?

Tror du att sättet man arbetar med konceptutveckling idag behöver ändras? Varför/varför inte?

Hur skulle du definiera ett modernt arbetssätt inom konceptutveckling för produkter?

G2. Tekniska simuleringar

Vilka faktorer tror du påverkar användandet av tekniska simuleringar, vad uppmuntrar användandet och vilka svårigheter finns det?

Vilka tror ni nyttjar era produkter och sitter med de tekniska simuleringarna ni levererar till er kund?

Vilken utbildning står ni för som mjukvaruleverantör till de företag som köper era tjänster?

Upplever ni att ni som mjukvaruleverantör har ett ansvar att integrationen mellan programvaror ska fungera? Varför/varför inte?

Har ni någon form av kategorisering av era programvaror beroende på hur avancerade de är? Förklara

G3. Tekniska simuleringar och konceptutveckling

Hur kan tekniska simuleringar användas i konceptutvecklingen?

Vilka faktorer tror du påverkar användandet av tekniska simuleringar i en tidig konceptutveckling, vad uppmuntrar det och vilka svårigheter finns?

G4. Tekniska simuleringar och modern konceptutveckling

Hur tror du att användandet av tekniska simuleringar skulle kunna stötta det moderna arbetssättet?

Tror du användandet av tekniska simuleringar kan försvåra utvecklingen av ett modernt arbetssätt? Varför/Varför inte?