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Concept Development Toolbox

Development of a methodology for structured and pragmatic concept development at Husqvarna Construction Products

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Master's thesis 2021

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Cover: Depiction of a Toolbox providing instructions and support for practical application.

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Abstract

Focusing efforts early in projects and working with structured and purposive methods can prevent changes in the later stages of product development projects, which can be costly and have detrimental effects for time-to-market. To maintain a strong market presence and competitiveness in R&D operations Husqvarna Construction Products are striving to continuously improve the time-to-market for complex product development projects. As a part of this endeavor, Husqvarna Construction Products wants to study improvement potentials in early project phases, with the goal to find ways to work more structured and purposive with concept development execution.

The purpose of this project is to develop a Toolbox aimed to support structured and pragmatic development execution in early product development project phases where the conceptual design is performed. This project will support the improvement of early project phases as a part of Husqvarna Construction Products' endeavor of reducing time-to-market for their product development projects. To achieve the purpose the research methodology comprised literature studies to research concept development methodologies, qualitative interviews to understand the current situation and needs at Husqvarna Construction Products and an iterative creation process for the Toolbox undertaken by an action-research approach involving participants from Husqvarna Construction Products.

The Concept Development Toolbox comprises a methodology derived from established concept development methodologies, further adapted to suit the needs of Husqvarna Construction Products. The methodology's core is to explore broadly, consider sets of solutions, and gradually narrow the sets by eliminating solutions, leading to convergence towards a final concept. It is influenced by the set-based approach, which supports considerations of several alternative solutions and prevents the appearance of late changes in the product development process. The Toolbox consists of two parts, a Handbook, and a Template. The Handbook aims to describe the methodology, the purpose, and how to execute activities. The Template aims to support the practical execution and facilitate documentation, by providing templates for each presented method and tool suggested in the Handbook.

Concluding, the Toolbox is developed to support and facilitate structured and pragmatic concept development execution for Husqvarna Construction Products and a prerequisite for obtaining the benefits entailed from the Toolbox is to implement it in the current concept development processes at Husqvarna Construction Products. The Toolbox provides a baseline for continuous adaptations and improvement based on new needs and insights and the result presented now should be considered as a starting point in the endeavor of improving concept development execution at Husqvarna Construction Products.

Keywords: *Concept development, Design methodologies, Husqvarna Construction Products, Set-based concurrent engineering, Product development.*

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Next, we would like to thank our Supervisor Martin T Huber (R&D Director, Concrete Surfaces and Floor, Husqvarna Construction Products) for giving us this opportunity, sharing his opinions and knowledge during weekly meetings, as well as valuable insights into Husqvarna Construction Products and what concept development look like in the industry.

We are truly thankful to all interviewees at Husqvarna Construction Products, Husqvarna Brand, and Gardena for their contribution to this thesis. Their participation and input have provided us with knowledge and understanding for concept development at Husqvarna, how it works, and its challenges, which without this thesis would not have been possible. A special thanks to Dan A Paulsson, Vladimir Gutic, Tobias Gustafsson, Anders Laag, Mats Lawenius, and Shreyasu Subramanya for your collaboration as action research candidates and for providing valuable inputs during the creation process of the Concept Development Toolbox.

Matilda Alfredsson & Olivia Andersson
Gothenburg, June 2021

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1 Introduction

This report is a result of a master thesis project conducted at Chalmers University of Technology in collaboration with Husqvarna Construction Products. The purpose of this project is to develop a Toolbox aimed to support structured and pragmatic development execution in early product development project phases where the conceptual design is performed. This chapter describes the background to the project as well as the case company, followed by purpose & research questions, objectives, and lastly scope & delimitation.

1.1 Background

1.1.1 Concept Development

Front-end activities, covering the work preceding the actual product design, is a critical part of product development projects and it is claimed that the ability to influence the success of a product development project is never greater than at the start of the project (Cooper, 2019; Morgan & Liker, 2006; Ulrich & Eppinger, 2016). Learning at the front and focusing efforts on front-end activities in a project prevents late-cycle changes in design. Changing course in a project becomes increasingly more expensive and time-consuming as the project progresses, and many times delays the time-to-market for the product.

Concept development is a front-end process that takes place in the early phases of product development projects. The purpose of concept development is to create, evaluate and decide on one or several product concepts for further development and testing, based on an identified opportunity or idea. The term concept refers to a means with information about the form, function, and features of a product, that can be used to estimate cost, size, weight, and feasibility (Mattson & Sorensen, 2019; Ulrich & Eppinger, 2016). The process of concept development can be described as a phase to evolve information that characterizes the solution to be developed (Ulrich & Eppinger, 2016; Mattson & Sorensen, 2019). The decisions made during the process affect the subsequential development activities, and wrong decisions can have a tremendous negative influence on the development project.

Wrong decisions in development projects are often due to poor evidence behind them, and a way to manage this is by working with structured processes and methods. Structured processes and methods support the decision process, by creating an understanding of decisions and reduces the risks of moving forward with unsupported decisions. It also helps to manage complexity in development projects and ensures that important issues in development are not forgotten. Further, structured processes and methods can also help to capture knowledge and information that can be used as future reference and to educate newcomers, since structured methods are mostly self-documenting (Ulrich & Eppinger, 2016; Cooper & Kleinschmidt, 1995)

In a time where product development projects are facing challenges concerning tight time plans and pressure to improve the time-to-market, focusing efforts on working with structured processes and methods in concept development is seldom prioritized in product development projects since it intuitively can be perceived as costly, time-consuming, and result in longer development times. However, research shows that frontloading in development projects reduces development time and improves success rates (Cooper, 2019; Morgan & Liker, 2006).

1.1.2 Husqvarna Construction Products

Husqvarna Group is a Swedish world-leading producer of outdoor power products for forest, park, and garden care, watering products, and power tools for construction. In the year 1689, the company was founded and today Husqvarna Group has approximately 13,000 employees in 40 countries and a turnover of approximately SEK 42 billion per year (Husqvarna Group, 2021b). The Group consists of three divisions, Husqvarna Construction Products, Husqvarna Brand, and Gardena.

Husqvarna Construction Products is a global leader in machinery and diamond tools for the construction and stone industries with a strong focus on innovation and the customer. The product range consists of machines, diamond tools and accessories for cutting, sawing and drilling as well as polishing floors and demolition. The products are used exclusively by professionals and are built for high-level performance, reliability, and superior support (Husqvarna Construction Products, 2020). Their product range consists of large machines, hand-held machines, and smaller accessories. *Figure 1.1* show products within the whole product range, going from large demolition robots, floor grinders, hand-held electrical cutters, and small diamond blades and chains (Husqvarna Construction Products, 2021).

Figure 1.1: Husqvarna Construction Products product range (Husqvarna Construction Products, 2021)

Husqvarna Construction Products' global headquarter and R&D center are located in Jonsered, Sweden. The division contributed to 14% (5.85 MSEK) of Husqvarna Group's net sales in 2020 and has approximately 2000 employees worldwide, and sales in more than 70 countries (Husqvarna Group, 2021a). Husqvarna Construction Products is divided into six segments, four located in Jonsered: Concrete Surfaces Floors, Concrete Sawing Drilling, Light Demolition, and Aftermarket Connectivity; and two in Ath, Belgium: Diamond Stone and Tools. The division's products are manufactured at nine different facilities shared with the rest of the Husqvarna Group and can be found worldwide.

Husqvarna Construction Products has a strong market presence and strives to be a world leader in the trend towards the most innovative and sustainable products. The division also works actively with the development of user-centered products. To further strengthen their market positions and technology leadership the division is focused on growing both organically through new customers, products, services, and markets as well as through complementary acquisitions. By acquiring companies, the division has quickly increased its market shares, expanded its product portfolio, and also obtained access to new technology and knowledge. Since 2016, Husqvarna Construction Products has acquired as many as six companies, as a result of that, they have added a new business area and can now offer customers a complete range of solutions for all surface treatment needs (Husqvarna Group, 2021a).

To maintain a strong market presence and competitiveness in R&D operations Husqvarna Construction products are striving to continuously improve the time-to-market for complex product development projects. As a part of this endeavor, Husqvarna Construction Products wants to study improvement potentials in early project phases, where the conceptual design is performed, with the goal to find ways to work more structured and purposive with concept development execution.

1.2 Purpose & Research questions

The purpose of this project is to develop a Toolbox aimed to support structured and pragmatic development execution in early product development project phases where the conceptual design is performed. This project will support the improvement of early project phases as a part of Husqvarna Construction Products' endeavor of reducing time-to-market for their product development projects. The thesis answers the following research questions to support the development of the Toolbox:

1. What is the current state of the art in the industry and academia in terms of concept development approaches, processes, methods and tools?

2. How is concept development executed at Husqvarna Group and what appropriate and inappropriate practices does it imply?

3. What methodology should be proposed in the Toolbox and how should the Toolbox be designed to facilitate implementation and usage for structured and pragmatic concept development execution at Husqvarna Construction Products?

1.3 Objectives

The objective of this project is to reach user acceptance for the Concept Development Toolbox, to facilitate implementation and usage at Husqvarna Construction Products. Further objectives are related to long-term effects for Husqvarna Construction Products that implementation and usage of the Toolbox can entail, in terms of increased innovation, improved time-to-market, and maintained competitiveness in R&D operations.

1.4 Scope & Delimitation

The project comprise initial limitations set in accordance with the desired improvements of concept development execution presented by Husqvarna Construction Products. Certain delimitations were set due to the time constraints of the project. The scope and limitations listed below were used as a framework for the project.

- The Toolbox is developed to present a methodology prescribing activities of how to go from requirements to concept(s), considering functional analysis, concept generation, and concept decision making.

- The Toolbox is developed to facilitate concept development that considers several alternative solutions.

- The Toolbox comprises established concept development methods and tools that are modified to comply with the current situation and user needs at Husqvarna Construction Products.

- The Toolbox is developed for concept development work performed by the development team, and not for other functional areas that are involved in concept development work at Husqvarna Construction Products.

- The research of the state of the art of concept development approaches, processes, methods and tools in the industry is conducted with literature studies and interviews within Husqvarna Group.

- The project does not comprise the implementation of the Toolbox at Husqvarna Construction Products.

1.5 Outline of the report

This report is divided into seven chapters in the following order; Introduction, Methodology, Empirical setting, Theoretical frame of references, Results, Discussion, Conclusions & Recommendations.

Chapter 1 has presented a background to the project, including a description of concept development and Husqvarna Construction Products. The chapter also presented the project's purpose, research questions, objectives, as well as scope and delimitation.

The next chapter, 2, provides and justifies the project's methodology. First, the research approach is presented, followed by the research process, including a description of each phase. Lastly, the data collection methods and tools are presented, used throughout the project.

Chapter 3, describes the empirical settings including the Husqvarna Product Creation Process, and puts the concept development and associated roles & responsibility in a Husqvarna Construction Products context.

Chapter 4, presents the theoretical frame of references for this thesis. Firstly, the theory of design methodology, with the generic engineering design process and adaptation to different project types is presented. Followed by the generic concept development process and different approaches to concept development. Lastly, the theory about requirement management, functional analysis, creation of concepts, and decision-making in concept development is presented.

In chapter 5 the results of the project are presented. In the first part of the chapter findings related to the current situation at Husqvarna Construction Products are presented. In the second part of the chapter, the results of the creation process of the Concept Development Toolbox are presented.

Chapter 6 discusses the overall results concerning the project's purpose and research questions, as well as the methodology used in the project.

In the final chapter, 7, the conclusions and recommendations are stated.

Finally, the Concept Development Toolbox is provided as two appendices, the Concept Development Toolbox - Handbook and the Concept Development Toolbox - Template.

2 Methodology

In this chapter, the research methodology will be presented, including the research approach for the project, followed by a description of the research procedure and its different phases as well as data collection methods. The project consists of three phases, which has made it possible create a Toolbox aimed to support structured and pragmatic development execution in early product development project phases where the conceptual design is performed. In Figure 2.1, an overview of how the research was conducted along with a brief description of each phase can be seen.

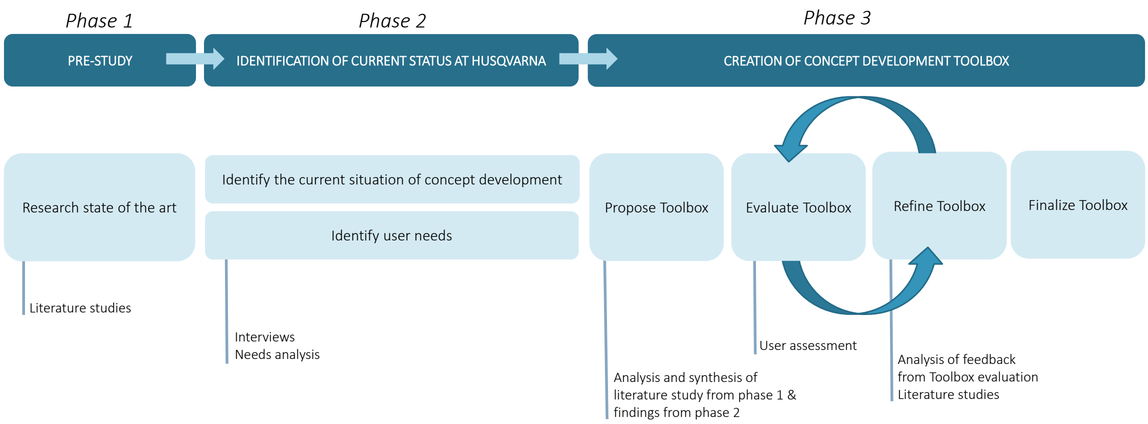

Figure 2.1: A process chart showing the project's methodology

2.1 Research approach

The project aimed to improve the current way of working with concept development at Husqvarna Construction Products. To succeed in this, the Toolbox had to be adapted to the users and systems at Husqvarna Construction Products. Hence, interaction with people directly affected by the improvements and people working with concept development in different areas at Husqvarna Group was crucial for this project.

The activities related to the concept development at Husqvarna Construction Products belong to the daily activities, and the Concept Development Toolbox will probably affect the daily operations. In accordance with that, a qualitative case study was a appropriate research approach. According to Baxter and Jack (2008), a qualitative case study is appropriate when exploring an everyday occurrence when the contextual conditions are important to take into account. In addition, the project also undertook an action research approach since that is suitable when a practical situation is to be understood and improved from a scientific perspective (Cassell & Johnson, 2006). Action research can provide good possibilities to evaluate new tools and methodology in relation to the existing procedure of concept development at Husqvarna Construction Products. This was accompanied by literature studies.

2.2 Research process

The project was divided into three phases and was carried out in a chronological order where one phase overlapped the next; pre-study, identification of current status of concept development, and creation of Concept Development Toolbox. Each phase involved one or several methods used to systematically propel the project forward. The phases were divided in accordance with the research questions that the project will answer. However, it is important to point out that one phase did not always only answer one research question, but certain phases examined and partly answered more than one research question.

The results that emerged in one phase did form the basis for the next phase and thus a phase outcome became an input in the next phase. It should be pointed out that the third phase differed in comparison with phases one and two. In the third phase, the action research approach the project did undertake was evident. The activities were carried out in an iterative manner and it facilitated gradual improvements and thus the quality of the final Concept Development Toolbox could be ensured to a higher degree. All three phases with associated activities are described in the sections below.

2.2.1 Pre-study

The first phase aimed to search for relevant literature in the area of concept development to get an understanding of how the state of art in academia and industry looks like as well as the advantages and disadvantages of methods and tools. At the same time, information about the case company, Husqvarna Construction Products, was collected. The literature review was conducted in a concentrated way along with frequent searching on Husqvarna Group's intranet for concept development process descriptions, roles & responsibilities related to concept development and other relevant documents. Literature related to concept development in academia could partly be found through the authors' own experience of literature in the field. During the literature study it was evident that there was a lack of literature describing the state of the art in the industry, but there was very interesting literature describing the state of the art in academia. Some authors who proved to be particularly interesting for this project were: Karl T Ulrich, Steven D Eppinger, Robert G Cooper, Jeffery K Liker, Allen C Ward, and Durward K Sobek.

At the end of this phase, the gathered literature and information were analyzed and compiled presented in *4 Theoretical frame of reference.*

2.2.2 Identification of current status of concept development

The second phase of the project aimed to identify the current status of concept development in different areas of Husqvarna Group. This was done through qualitative interviews with employees from different divisions within Husqvarna Group.

A total of 15 interviews were conducted in this phase, excluding ten weekly meetings with the company supervisor at Husqvarna Construction Products, Martin T Huber. In some interviews, there was more than one interviewee, which resulted in a total of

21 interviewees in this phase. One employee from Gardena, two employees from Husqvarna Brand and the remaining 18 employees Husqvarna Construction Products. The interviewees were selected based on a recommendation from the company supervisor Martin T Huber. The majority of the interviews were conducted through video calls for two reasons. Either the interviewee was placed elsewhere in Europe or working remotely from home, due to restrictions related to the Covid-19 outbreak.

The interviews provided a good overview and understanding of how different divisions within Husqvarna Group as well as different employees performed concept development activities, in terms of what tools they are currently using, and what appropriate and/or inappropriate practices it implied. Furthermore, opinions, experiences, and feelings related to the current concept development process, methods, and tools among employees at Husqvarna Construction Products were explored. Other interesting aspects related to concept development, which are not within the project scope, also emerged during the interviews. Through the interview data collected in this phase, the needs of the employee at Husqvarna Construction Products could be identified. This was done through a needs analysis, and the needs were reflected in points of departure.

At the end of this phase, the collected data were analyzed. All data from the interviews were compiled into one document and then categorized in an iterative manner until four significant themes had emerged: Approach to concept development, Frontloading, Integration of perspective, Documentation.

The result from this phase is presented in section *5.1 Current situation at Husqvarna Construction Products* and will provide answers to research question two as well as partly one and three.

2.2.3 Creation of Concept Development Toolbox

The third and final phase of the project constituted the actual development of the Toolbox aimed to support structured and pragmatic development execution in early product development project phases where the conceptual design is performed. In this phase, the action research approach was used, which involved voluntary practitioners from Husqvarna Construction Products.To obtain user acceptance of the Concept Development Toolbox, the creation of the Toolbox was done iteratively with the involvement of candidates from Husqvarna Construction Products. At the beginning of this phase, all 18 interviewees from phase two were asked if they wanted to participate as practitioners in the action research, of which seven chose to say yes.

The first step in this phase was to propose an initial Toolbox to the seven practitioners, based on analysis and synthesis of results from phase one and two. The analysis and synthesis phase one and two outlaid points of departure for the creation process. The proposition was presented to the practitioners through email, with the Toolbox as an attachment. The email was sent separately to each practitioner where the researchers wrote that the review of the Toolbox should be done when time allowed. The email was sent separately to each practitioner where the researchers wrote that all types of feedback were welcome but appreciated feedback considering; the fulfillment of the

Toolbox's purpose, ease of use: practically applicable, understandable, and if there were absence or abundance of methods, tools or instructions. In addition, the email had an explanation of the purpose of the Toolbox and what the Toolbox consisted of. The practitioner had about a week to read through and review the Toolbox.

In the second step, the proposed Toolbox was evaluated together with the practitioners, through 30 minutes one-to-one meetings through video calls. In this step user assessment was essential for reaching user acceptance and creating something that would be of use for the development teams at Husqvarna Construction Products. The original idea was to have seminars and workshop sessions alongside one-on-one meetings. Seminars and workshops had enabled practitioners to evaluate its practicality by using the Toolbox during the sessions. Due to restrictions related to Covid-19 as well as employees' tight schedules, it was difficult to arrange physical and longer meetings meant that seminars and workshops were excluded. In the third step, the feedback from the practitioner was analyzed and the Toolbox was refined. The second and third steps were iterated twice, with a refined and changed Toolbox after each iteration. Step two and three created feedback loops. During the iterations when feedback from practitioners was received, additional literature reviews were performed. As the last step in this phase, a finalized Toolbox consisting of a Handbook and Template was presented.

The result from this phase is presented in section *5.2 Creation of Concept Development Toolbox* and will provide answers to research question three.

2.3 Data collection

In this project data has been collected through literature studies, exploratory semi-structured interviews with 21 employees at Husqvarna Group, action research with the involvement of seven employees from Husqvarna Construction Products as well as Husqvarna Group's intranet.

2.3.1 Literature review

Conducting a literature review in a research project is recommended according to Denzin and Lincoln (2008). It's beneficial because it increases the validity of the research project as well as elicits critical and analytical considerations. In this project, secondary sources were used to gather information and were considered to be appropriate since the aim was to draw unbiased conclusions about the state of knowledge within a specific topic (Denscombe, 2014). According to Denscombe (2014), secondary information search is advantageous because it allows access to information in an easy and quick way.

When the literature search was performed, keywords such as "concept development", "lean product development", “pre-development”, "concept elimination", “concept development in industry”, “Set-Based Design”, “SBCE”, “Practical application of ..”, “concept development tools & methods”, “concept creation/generation”, “target specifications”. The keywords were used individually but also in combination as search phrases in library databases such as Chalmers University Library database and Google

Scholar. The literature was selected based on relevance to the subject. Furthermore, the literature search was also done by examining the reference list of articles that were considered relevant. Literature related to concept development in academia could partly be found through the authors' own experience of literature in the field. During the literature review some authors who proved to be particularly interesting for this project were: Karl T Ulrich, Steven D Eppinger, Robert G Cooper, Jeffery K Liker, Allen C Ward, and Durward K Sobek.

All relevant literature that was found was listed in a document, where the name of the literature, author, year of publication, a brief description, and where it could be found were compiled.

2.3.2 Action research

The main viewpoint with action research is to integrate science and practice in order to improve a complex situation (Cassell & Johnson, 2006). According to Svensson (2002) it is important to emphasize that the intention of action research is a close collaboration between the researcher and the practitioner in order to reach a common insight regarding the best way to achieve the desired change. Collaboration between researchers and practitioners took place in this project in order to share knowledge from different aspects of the area and learn from each other to find the best practical solution adapted to the situation at Husqvarna Construction Products. The researchers shared their theoretical knowledge related to the subject of concept development, while the practitioners mainly shared their experiences and insights of practical work with concept development.

In action research, the roles and interactions between researchers and practitioners vary, and how this is defined will affect the action research approach to related activity within the project. In some parts of a project, there may be good reasons to involve the practitioners and let them make decisions. On the other hand, there may be resource reasons, knowledge reasons or other reasons against active collaboration between the researchers and practitioners (Chrisholm, 1993; Goldkuhl, 2012). How the role of researchers and practitioners was in the third phase of the project is shown in *Figure 2.2*, after Chisholm and Elden (1993).

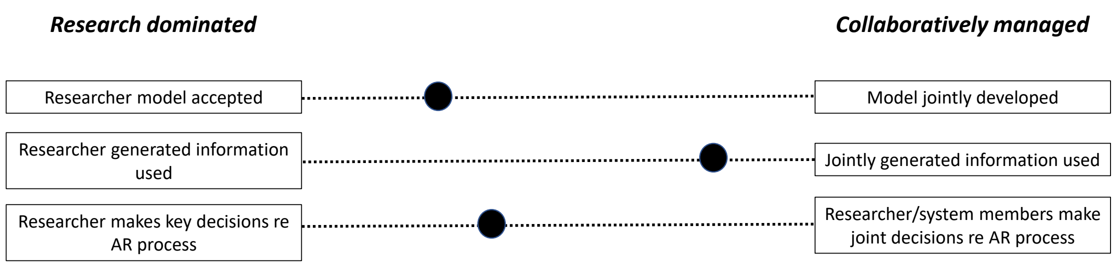

Figure 2.2: Researchers role in the action research (after Chisholm and Elden, 1993)

In this project, the researchers made the key decisions about the action research process. However, it should be pointed out that the practitioners' availability, as well as opinions, did influence where and how the activities did take place. Due to practitioners' tight schedules, short one-to-one meetings were performed through video calls. In the second and last iteration, one practitioner gave feedback through email instead of verbally.

During the action research, the researchers presented an initial Toolbox based on analysis and synthesis of results from phases one and two as well as the refined Toolboxes based on feedback from practitioners. The original idea was that practitioners would take an active role in the creation of the Toolbox and thus action research would be fairly neutral between research-dominated and collaborative. Due to lack of time, this was not the case, practitioners did not take an active role in the creation of the Toolbox. Thus, the action research in the project was more towards the research model accepted and more research-dominated than collaborative. The majority of the knowledge and information used in the third phase was generated by the researchers and practitioners together.

2.3.3 Data sources

The two main data sources during the project were organizational data and interview data. How this data was obtained during the project is described below.

Organizational data

To gain an understanding of Husqvarna Construction Products and the concept development process, documents were collected from Husqvarna Group's intranet. The documents consisted of process descriptions, roles & responsibilities, as well as figures to visualize. In addition, some internal documents, not published on the intranet, were received. Which described process improvements and templates to support concept development execution.

Interviews

An exploratory approach was used during the interviews.The purpose of the interviews was to get insight and broadly explore the interviewees opinions, experiences, and feelings related to concept development, hence exploratory sampling is a suitable option (Denscombe, 2014).

The interviews were semi-structured with defined themes and issues to address, but with a flexible approach giving the interviewee space to elaborate on points of interest, which is considered to be a suitable structure given the exploratory and qualitative research approach (Denscombe, 2014). The themes and issues to address during the interviews were the following; Understand how the interviewee works with concept development considering requirements, concept generation, concept decision-making, and documentation as well as strengths and weaknesses with the current concept development process. At the end of all interviews, the interviewees were encouraged to give any additional feedback they may have had.

The majority of the interviewees were chosen on the recommendation of the company supervisor, Martin T Huber. However, five out of 21 interviewees were found through recommendations during interviews, called snowball sampling. According to Creswell and Creswell (2017), snowball sampling is suitable for qualitative studies and provides ways to obtain the requested information. The interviewees were employees who in one way or another worked with concept development. *Table 2.1* shows the interviewees' roles and which division within the Husqvarna Group they belong to. They are not listed in chronological order according to when they were interviewed. Those seven who are highlighted in the table are those who participated in the action research in phase three.

Table 2.1: List of interviewees

Role	Division
Calculation Engineer	*Husqvarna Construction Products*
Engineering Lead	
Pre-Development Engineer	
Primary Engineer	
Primary Engineer	
Product Engineer	
Project Manager	
Project Manager	
R&D Director	
R&D Director	
R&D Manager	
R&D Manager	
R&D Manager	
R&D Manager	
R&D Manager	
R&D Manager	
Senior Design Engineer	
Senior Research Engineer	
Director Technology Development	*Gardena*
Team Manager	*Husqvarna Brand*
Manager Primary & Concept Development	

Depending on the mother tongue of the interviewee, either Swedish or English was used as the language of the interview. Whenever possible, Swedish was used because it was the mother tongue of both the interviewers and the interviewees, which made it possible for the participants to express themselves easily. Of 15 interviews, eight were conducted with one participant at a time, and the remaining seven interviews in groups of approximately two-four participants. The decision to conduct group interviews was at the initiative of the company supervisor, Martin T Huber. In those cases, the employees had the same role at Husqvarna Construction Products.

The majority of the interviews were conducted through video calls for two reasons. Either the interviewee was placed elsewhere in Europe or working remotely from home, due to restrictions related to the Covid-19 outbreak. During the interviews, one interviewer kept notes, either on a computer or by hand, while the other asked questions. According to Bell et al. (2018) , taking notes is an action in order not to distort the interviewee's answers and to reduce the number of errors in the data.

Conversation and narrative approach described by Denscombe (2014) was used when analyzing the data created during the interviews. In the *Table 2.2* below the conversation and narrative approach can be seen. The data analyzed were text and talk, and the purpose of the analysis was mainly to reveal the underlying rules and structure of a talk. The units analyzed were either blocks of text or a whole story, and the data were treated either by trying to display underlying rules or to find the symbolic significance of a story.

Table 2.2: Comparison of conversation and narrative analysis (after Denscombe, 2014)

	Conversation analysis	Narrative analysis
Purpose of analysis	Reveal underlying rules and structure of talk and interaction	Depict constructions of personal identity and social worlds
Data	Text and talk	Text and talk
Significance data	Displayed meaning	Implied meaning
Units of analysis	Blocks of text or talk	Whole story or text
Treatment of data	Deconstructed (to display underlying rules)	Deciphered (to find symbolic significance of story)
Data of analysis	Sequence and structure of talk	Structure or social implications of the text

The data were analyzed in five steps on the recommendation of Denscombe (2014). Step one was data preparation, where all text was gathered in one document. The second step was to initially explore the data, by looking for obvious themes. This was followed by step three where the data was grouped into four main categories of themes, with underlying categories under each theme. In the fourth step, data were interpreted and written in text blocks, which can be found in section *5.1*. In the last step, interview data were validated by each interviewee on request through email. Each interviewee received an individual email in which several points that summarized the interview data from that interview had to be approved.

3 Empirical setting

This chapter aims to describe the Husqvarna Product Creation Process in order to place concept development and associated roles & responsibility in a context and get a brief understanding of concept development at Husqvarna Construction Products. The description is based on documents on Husqvarna Group's intranet, internal documents, not published on the intranet, and information gathered during interviews.

3.1 Husqvarna Product Creation Process

Husqvarna Construction Products does not have an own organization for process development, which means that they do not have any resources for developing their own processes particularly adapted for the products they develop. At the moment they are instructed to abide by processes that Husqvarna Brand has developed for their purpose. In this project, the Product Creation Process is of interest. The process describes how the development of products and services takes place, which concept development is a part of.

The Product Creation Process is the overall process description, it consists of processes for all parts of the product lifecycle, from ideation to product elimination. The Product Creation Process also consists of formal roles & responsibilities. The process is based on a stage-gate model, where projects are managed through distinct stages separated by gates. The gates act as quality checkpoints for the project and decide whether the project is ready to proceed to the next stage. There are traditionally four distinct decisions in a gate review; let the project continue to the next stage, terminate the project, redo parts of the previous stage or hold the decision until further notice. These decisions are often handled by a steering committee that makes the decision based on whether the criteria for passing the current gate is adequately fulfilled (Cooper, 1990). In the Product Creation Process, technical readiness level (TRL) is used as a measurement system to assess the level of maturity for a particular technology and thus the product idea at the gates. To pass the current gate, the idea must reach the expected TRL. The scale for TRL ranges from 1 to 9 with 9 being the most mature technology level.

A challenge with the current design of the Product Creation Process according to Husqvarna Constructions Products is the transfer between Primary Development and Pre-Study, in several projects the product's maturity level has not been at a required level when it is received in the Pre-Study. Due to this, an additional phase between Primary Development and Pre-Study is currently being introduced, called R&D Pre-Development. The new phase will enable the product to be developed to a required level of maturity before it is transferred to Pre-Study. The scope of this project is focused on phases where concept development takes place in the Product Creation Process, thus Primary Development, R&D Pre-Development, Pre-Study, and New Product Development are of interest. The entire Product Creation Process is illustrated in *Figure 3.1* below, with the research scope highlighted.

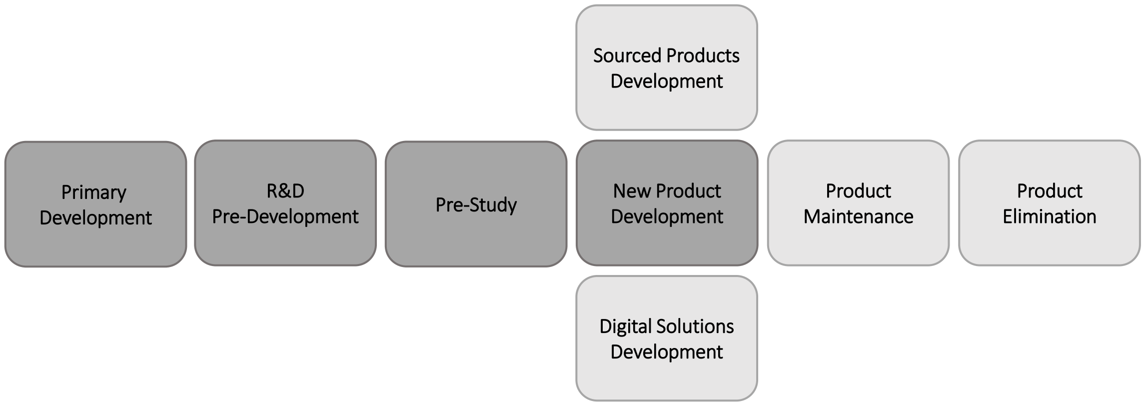

Figure 3.1: The Product Creation Process with the research scope of the project highlighted

According to Husqvarna Constructions Products, the use of TRL enables consistent, uniform discussions about technical maturity across different types of technology. However, there are ambiguities about the definition of when a phase is considered complete and achieves a sufficiently high maturity for a particular technology. Anyway, the definition of the phases, including the recently introduced R&D Pre-Development, in relation to the TRL is presented in *Figure 3.2*. The concept development takes place up to TRL 4 and sometimes to TRL 5. It should be mentioned that the level of detail in the concepts differs depending on where the concept development takes place in the Product Creation Process.

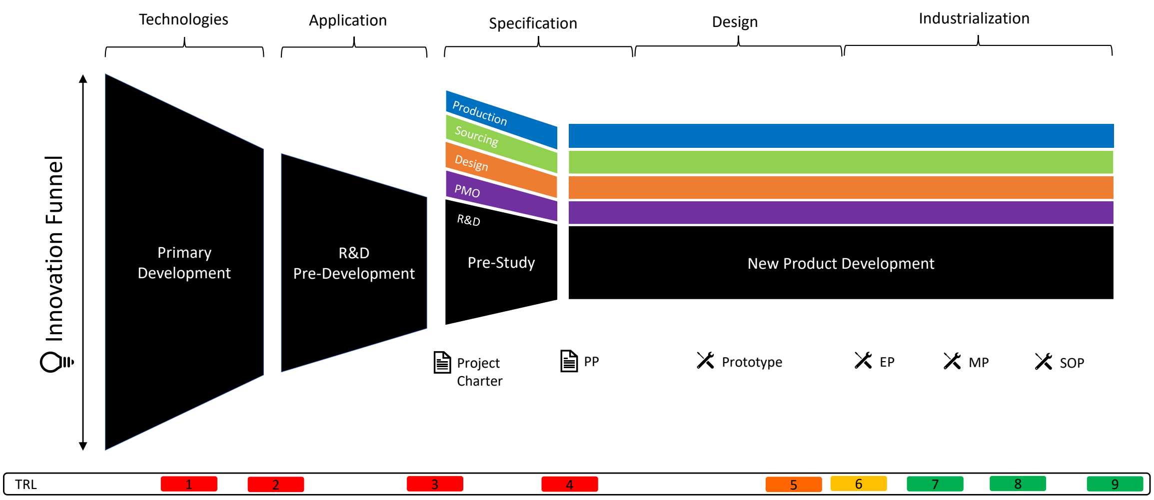

Figure 3.2: TRL in relation to the phases of interest in the Product Creation Process

3.1.1 Primary Development

The purpose of Primary Development is to systematically test and evaluate new technologies for the eventual creation of new or next-generation products, service solutions, and production methods. By aiming to reduce uncertainties concerning issues about technology, feasibility, cost, and time of such magnitude that it cannot be handled in New Product Development projects.

Research areas for Primary Development are selected to support concepts and product generations, established in the generation plan. Primary Development projects can be large or small, theoretical or concrete, technical or market-oriented. The factor common for all Primary Development projects is a high degree of uncertainty with a goal to explore future product possibilities. Primary Development projects can end up either as verified ideas or as hardware solutions. A verified idea is a solution to a core problem, which has been evaluated and tested, and a hardware solution has been realized as a functional prototype. Results of Primary Development are stored in a bank, and can be taken to the R&D Pre-Development, Pre-study and New Product Development at a suitable point in time.

In Primary Development, concept development takes place in the concept stage. It starts with R&D receiving market input data from the product manager, and then R&D execute following activities: technical benchmark, external expertise, patent landscape, list potential concept(s), create mock-up and simulate, evaluate, robust design, pro/con list, and recommendation of concept choice. How the activities shall be executed or suggestions for suitable tools and methods are not stated in the Product Creation Process. The purpose of the concept stage is to choose a concept(s) to take into the feasibility stage. In the Product Creation Process, the project manager is stated as responsible for the execution and deliveries from the concept stage.

The Primary Development phase is considered complete according to the original Product Creation Process when the product idea has reached TRL 3, which is an experimental proof of idea or concept. Now when the Product Creation Process has been modified with a new phase introduced, R&D Pre-Development, Primary Development is considered to be completed at TRL 2.

3.1.2 R&D Pre-Development

The purpose of R&D Pre-Development is for R&D teams to work proactively with predevelopment activities according to a document called innovation runway. With the help of an innovation runway, R&D decides together with each product manager what they need to focus on in order to develop even more purposive and successful products. The aim is to look ahead and determine which technologies need to be developed to make them mature enough to put into a New Product Development project. In this phase, each R&D manager is responsible.

Questions to be answered are; What needs to be solved according to the stakeholders? What level of maturity is the technology today? What activities are needed to develop the technology to TRL 4?

The R&D Pre-Development phase is considered complete when the product idea has reached TRL 3, which is pre-prototypes that can verify the function in a relevant application environment.

3.1.3 Pre-Study

The purpose of the Pre-Study is to seek approval from the company management to progress with a product idea and to start a project. This is done through a project proposal that contains relevant information about the proposal's impact on the company's operations, i.e.: overall group strategies, product strategy for group, division and category, product portfolio plans, market and competitor situation, trends & technologies, and financial impact. The product manager is responsible for this phase, thus submitting the signed project initiation template to the project management office after the proposal has been approved. Project management office then assigns a project leader who prepares an initiation of the next phase, New Product Development.

The concept development work in this phase is initiated when system requirements are to be defined by R&D. Once system requirements are defined, R&D and Global Design together execute the following activities; create & build technology and usability system concepts as well as evaluate concepts. R&D is responsible for the technical aspects and Global design is responsible for the design. At the end of this phase, all subsystems must be analyzed, developed, and verified to comply with TRL 4.

3.1.4 New Product Development

The purpose of the New Product Development is to ensure a common framework and objectives, enabling a project to efficiently define, develop and launch new products. The process is intended for projects with internal development and manufacturing.

The first stage in New Product Development is the specification stage and where the concept development work takes place. The purpose is to generate possible concepts to be evaluated and then decide on a concept that has the potential to meet the agreed product specification requirements and product compliance specification. A structured development approach shall be used, and set-based concurrent engineering is suggested. To assist the R&D team in deciding which concept is most appropriate, it is suggested that a concept selection matrix could be used, assigning numerical values to the benefits, drawbacks, and risks of each concept. During the activity the R&D Lead is responsible.

The specification stage ends somewhere between TRL 4 and TRL 5 and thus concept development takes place up to that level. Husqvarna Construction Products definition of TRL 4 is; Basic technological components integrated and verified they will work together. Examples include integration of ad hoc hardware demonstrated in laboratory environment. Theirs definition of TRL 5 is; The basic technological components are integrated with reasonably realistic supporting elements and a representative system prototype of the technology can be demonstrated in key test environment.

The entire phase, New Product Development, is completed when TRL 9 is reached with serial production of units that fulfill the requirements specification.

3.1.5 Roles & Responsibilities

Where and to what extent concept development takes place at Husqvarna Construction Products is not clearly described in the Product Creation Process, which makes it difficult to define exactly which roles are involved in concept development and what their responsibilities are. The following roles and responsibilities are described at an overall level to get an idea of how they differ.

Project management office

The project management office is the function that organizes the project managers. Each manager has full ownership of a number of assigned project(s). The responsibility is to drive the project(s) towards defined and agreed results as well as managing the full range of stakeholders.

Key tasks for the project manager include forming the project teams, clarifying the responsibilities for all roles, securing resource alignment with the organization, reporting progress to the steering committee, communicating with all relevant stakeholders, creating and maintaining the project budget, and ensuring that the project can pass the current gate.

Product manager

The product manager is responsible for the company's product portfolio. The product manager represents the market and is, therefore, the one who proposes the development of new products. Key tasks are to conduct market research, create a business case for the product, compile market and user requirements, provide recommendations for prioritization between quality, time, project, and product cost and support the marketing and sales organization.

During a product development project, the product manager works closely with the project manager but also cooperates with R&D to translate market & stakeholder requirements into more technical stakeholder requirements.

R&D

R&D is responsible for the actual research & development and in each phase of the Product Creation Process. The R&D function itself is divided into the following roles; R&D managers, R&D lead, mechatronics engineers, electronics engineers, software engineers, and test & verification engineers.

The R&D managers have overall responsibility for a group of projects and thus responsible for several R&D projects in parallel. Key tasks for an R&D manager are to keep track of the status of each project, update the innovation runway, as well as staff liability for a group of employees.

The R&D lead has the authority to make technical decisions regarding the design of a new product in a project. The R&D lead key tasks include securing R&D deliveries according to the project schedule, leading planning and control of the R&D team's execution, communicating necessary resources and requirements to the project manager, and driving the project's technical progress.

An R&D team consists of a number of engineers and the main task is to actually execute the research & development. It is the R&D lead and team together with the project manager that form the core of a development group.

Global Design

Global design is responsible for the product design and ensures that it complies with Husqvarna's brand. This includes that colors, shapes, and logos are in line with Husqvarna.

4 Theoretical frame of reference

This chapter presents the theory for this thesis and is the results from the literature review explained in Chapter 2 Methodology. The first part of this chapter aims to describe the theory of design methodology, with the generic engineering design process and adaptation to different project types. Furthermore, the generic concept development process is described. The final part of this chapter describes the theory of approaches to concept development as well as requirement management, functional analysis, creation of concepts, and decision-making in concept development.

4.1 Design methodology

Industrial product development often uses formal design methodologies to create products, services, and systems. Design methodologies provide a structured, repeatable process for developing new products to enter the market and can be described as a set of activities that are performed to go from an idea and/or opportunity, ending in production, sale, and delivery of a product (Wheelwright & Clark, 1992; Ulrich & Eppinger, 2016). There is no universally defined process for engineering design, however, in literature you can find several different design methodologies, prescribing similar structures of common phases. The structures encompass different phases, beginning with some kind of opportunity identification, concept generation, moving on to more formal development, and concluded with production or sales. This chapter will present a generic engineering design process described by Ulrich and Eppinger (2016), to present the context for concept development as a part of engineering design methodologies in product development.

4.1.1 The generic engineering design process

The generic design process for product development described by Ulrich and Eppinger (2016), consists of six different phases, seen in *Figure 4.1*. Each phase serves a different purpose, which will be further explained in the following sections.

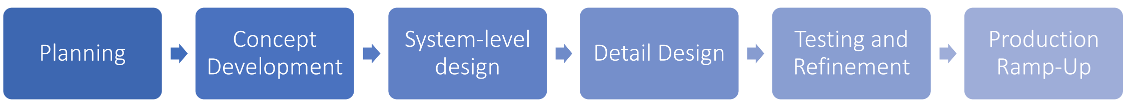

Figure 4.1: The generic product development process (Ulrich and Eppinger, 2016)

The planning phase serves the purpose of identifying opportunities guided by corporate strategy and includes both market and technology assessments. In this phase, the development task is clarified and provides specifications of products, business goals, key assumptions, and constraints. Following is the concept development phase, where the search of possible solutions takes place, to find one or several concepts to further refine and develop in upcoming phases.

The system-level design phase further develops the concept by defining the product architecture, with system-and functional descriptions. Detail design takes place after the product architecture is defined and serves the purpose of providing detailed information of the product and upcoming activities, such as detailed drawings/models of product design, complete specifications, and production plans.

The second last phase, testing and refinement, serve the purpose of testing that the product will work as designed, the satisfaction of customer needs, and to identify necessary engineering changes for the final product before production. Lastly, the phase of production ramp-up takes place with the purpose to train the workforce and to identify and fix the remaining problems in production processes, before going into production.

4.1.1.1 Adaptation to project types

The choice of process for product development can differ in accordance with the firm, context, and the specific project type. According to Cooper (2019), an important practice for successful processes is that they allow for adaption and iteration, to be useful for different types of product development projects. The generic product development process presented in the previous section is designed for market-pull projects but can easily be adapted to suit other types of projects. Different definitions of project types are described in literature, but commonly they are defined by the type of product that aims to be developed. *Table 4.1*, modified from Ulrich and Eppinger (2016), summarizes different project types and how distinct features of how the generic process can be adapted to fit the specific project type.

Table 4.1: Variants of the generic product develop process adapted to product type (after Ulrich and Eppinger, 2016)

Process type	Description	Distinct features	Examples
Market-pull products	The team begins with a market opportunity and selects appropriate technologies to meet customer needs.	Generic process, including planning, concept development, system-level design, testing and refinement, and production ramp-up phases.	Sporting goods, furniture, tools.
Technology-push products	The team starts with a new technology, then find ans appropriate market	Planning phase involves matching technology and market. The concept development assumes a given technology	Gore-Tex rainwear, Tyvek envelopes.
Platform products	The team assumes that the new product will be built around an established technological sub-system.	Concept development assumes a proven technology platform.	Consumer electronics, computers, printers.
Customized products	New products are slight variations of existing configurations	Similarity of projects allows for streamlined and highly structured development process	Motors, switchers, batteries, containers.
Quick-build products	Rapid modeling and prototyping enable many design-build-test cycles	Detail design and testing phases are repeated a number of times until the product is completed or time/budget runs out.	Software, cellular, phones.
Complex systems	System must be decomposed into several sub-systems and many components	Sub-systems and components are developed by many teams working in parallel, followed by system integration and validation	Airplanes, jet engines, automobiles.

4.1.2 The generic concept development process

The process of concept development can be generally described by a set of activities, but it can differ depending on the unique context for the project and the firm using it. As for the product development process, there is no universally defined process for concept development, but similar activities are presented in different frameworks. For this thesis, a generic concept development process described by Ulrich and Eppinger (2016) will be presented.

Figure 4.2 shows the generic concept development process as a set of sequential activities, which is often the case men describing processes. However, iteration is often necessary and different steps within the process may be repeated based on newly available information or learning from results (Ulrich & Eppinger, 2016).

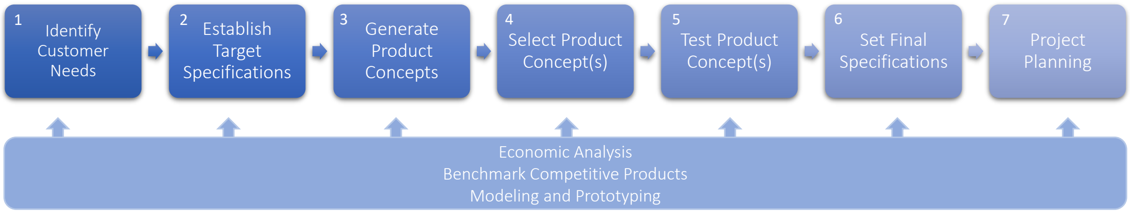

Figure 4.2: The generic concept development process (Ulrich and Eppinger, 2016)

The purpose of the activity of identifying customer needs is to get a better understanding of the customer and their needs and to effectively communicate them to the development team. Getting a better understanding of the customer is important since it gives the development team the possibility of anticipating problems and opportunities early in development (Wheelwright & Clark, 1992).

Identification of customer needs is followed by the activity of establishing target specifications, by translating customer needs into technical terms. Established target specifications provide a description of what a product must do, and each specification usually consists of a metric, marginal and ideal value for it. Target specifications are initially established early in the development process, but further refined to be consistent with selected product concepts.

Concept creation is an activity with the purpose to explore the space of product concepts that may address the customer needs (Ulrich & Eppinger, 2016). Mattson and Sorensen (2019) describes the possibility of identifying the best concept can only be done in the context of multiple concepts. The selection of concepts is done by analyzing, evaluating, and eliminating concepts until the most promising concepts are left. For this activity, iteration is usually required and combinations and improvements of concepts can be performed throughout the activity (Ulrich & Eppinger, 2016; Mattson & Sorensen, 2019).

Concept testing is an activity to verify that the selected concept meets customer needs, to assess market potential, and identify problems needed to be fixed before further development. If the concept is not performing well in the tests and the development team does not believe in the selected concepts, it is necessary to repeat the previous activities. (Ulrich & Eppinger, 2016; Mattson & Sorensen, 2019).

After a concept is selected and tested, the activity that follows is to revise the initially established specifications according to the selected concept. Constraints inherent in the product concept, limitations identified through technical modeling, and trade-offs between cost and performance should all be reflected with specific values in the target specifications, for the team to commit to in further development.

4.2 Approaches to concept development

The literature describes two distinguished ways to approach concept development, point-based and set-based. A point-based approach is described in the literature as the traditional approach commonly applied in industry. Set-based has received positive attention in the literature, which has led to an increased interest in the approach, however, it is not widely used in the industry. The literature describes the main principles of the approaches, but there is a lack of literature that describes how to apply the approaches in practice and which specific methods and tools can be used for execution. For example, there is no guidance on how to use specific tools and how much they can be modified to ease the execution.

4.2.1 Point-based

In a point-based approach, requirements and constraints are specified as early as possible and then adjusted minimally. A few concepts are then generated where one that seems promising is decided to be developed further, thus a single design solution has been chosen when the information and knowledge for the problem is usually low.

The decision-making process when selecting a promising concept is early in the process and usually based on the assessment of the engineers involved in the concept development phase and which concept, they believe will fulfill the requirements. The assessment is therefore based on intuition or the experience of these engineers. Once a concept is selected, the detailed design is established and evaluated through prototyping and testing, this is done iteratively and the design is modified until it fulfills the requirements (Camarda, Scotti, Kunttu, & Perttula, 2019; Liker, Sobek, Ward, & Cristiano, 1996; Ward, Liker, Cristiano, Sobek, et al., 1995; Holmdahl, 2010; Kennedy, 2003). In *Figure 4.3* the point-based approach is illustrated.

The main disadvantage of a point-based approach to concept development is that it forces an early decision on a design solution, and thus the product concept. Making a decision early when there are knowledge gaps about the chosen concept and the alternative concepts is problematic and instead means that the decision sometimes is based on a guess or a feeling. This means that there is a risk that a less appropriate concept has been chosen and when it is discovered, major adjustments may need to be made, which can be both time-consuming and costly. This concept development approach may therefore result in rework of certain or every phase of the concept development process in order to find an appropriate concept (Camarda et al., 2019; Liker et al., 1996; Holmdahl, 2010). On the other hand, a point-based approach is said to be efficient if firms have the ability to discern the quality of the concepts and design alternatives and pick an appropriate one from the beginning (Abernathy & Rosenbloom, 1969; Girotra, Terwiesch, & Ulrich, 2010).

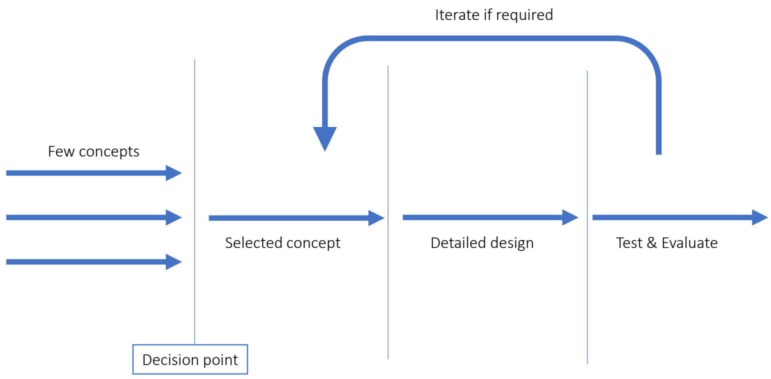

Figure 4.3: Visualization of the point-based approach (after Kennedy, 2003)

4.2.2 Set-based

A set-based approach to concept development is characterized by developing and managing several solutions to a problem, by considering sets of design alternatives rather than focusing on one specific. The decision point for concept selection is not made in the early development phases when taking on a set-based approach, as for the point-based approach. For set-based approaches, a thorough investigation of the design space is needed to converge on a final solution. With a set-based approach, illustrated in *Figure 4.4*, a wide set of possible solutions is considered and gradually narrowed by the elimination of solutions that are deemed unfeasible or inferior, leading to convergence towards a final solution (Sobek II, Ward, & Liker, 1999; Ward & Sobek II, 2014).

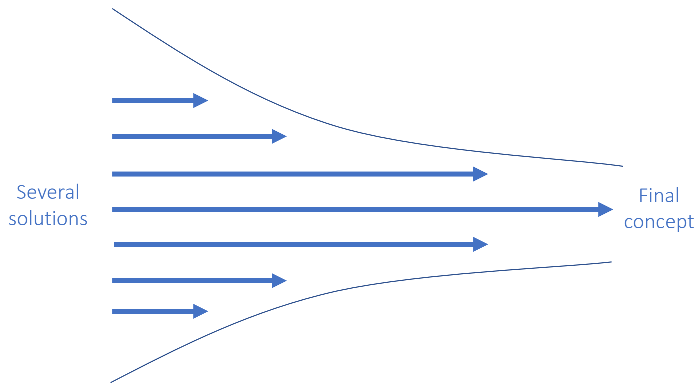

Figure 4.4: Visualization of the set-based approach

In literature, Set-based design and set-based concurrent engineering are the two terms occurring for describing the set-based approach. The two terms are related but distinguished as the set-based design is the practical approach to engineering design following the principles of Set-based concurrent engineering. The latter, Set-based concurrent engineering, is used to denote both Set-based concurrent engineering and Set-based design in this work.

Set-based concurrent engineering

Set-based concurrent engineering is a development approach, and a part of Lean product development, which derives from the Toyota development organization's development process (Ward et al., 1995). The set-based concurrent engineering approach has received positive attention and is claimed to provide benefits such as increased innovation and increased probability of successful design (Ward & Sobek II, 2014). Set-based concurrent engineering is also claimed to be much faster and less expensive than point-based approaches, because focusing efforts at the front and learning early on in a project prevents late-cycle design changes which are much more expensive, risky and time consuming (Ward & Sobek II, 2014). Set-based concurrent engineering is not a prescribed methodology, but rather an approach for development that is built on three principles, which needs to be adapted to each individual application. Sober et al. (1999) defines the three principles as presented in *Figure 4.5* below:

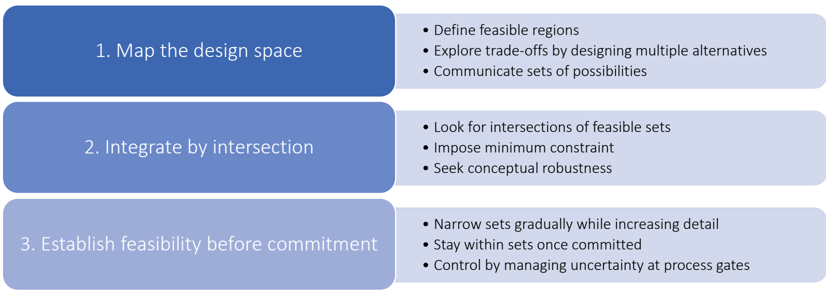

Figure 4.5: The three principles of set-based concurrent engineering (Sober et al., 1999)

Initially, it implies searching widely for possible solutions and defining the sets by designing multiple alternatives. Ward and Sobek (2014) explain that this can be done by first decomposing the system into the smallest parts possible, and then define broad targets and specifications for each part, followed by the generation of multiple concepts for the system and each part. Designing several alternatives allows for exploration and learning of each, and to identify trade-offs. Decomposing a system allows for focused development efforts and to take on tasks concurrently instead of sequentially, which Cooper (2019) describes to be a suitable approach for today's fast-paced projects and a principle that industries embrace for reducing time-to-market (Cooper, 2019).

The sets of solutions are gradually narrowed by elimination. Elimination is based on the evaluation of each of the different alternative solutions. Evaluation includes identification of failure modes and failure points for each alternative and finding trade-offs. The information of failure modes and points goes into trade-off curves that describe the given design approach's limits of performance possibilities, hence serving as a knowledge base to guide the design. Elimination is also done based on evaluation of integration, how well they fit with each other, fulfillment of customer's needs, the competitive situation, and other targets in the current specifications (Ward & Sobek II, 2014).

The gradual reduction of the different sets is done by elimination based on currently available information, knowledge, and trade-offs. If information of an alternative is not enough to decide on elimination, the alternative will remain in the set and additional information will be gathered. Additional information can be gathered through further development and analysis, research, and other functional areas (Liker et al., 1996).

In set-based concurrent engingeering, the specifications are initially defined by broad intervals instead of specific target values. Defining it broadly initially provides flexibility in the design process, but the requirements specifications are more detailed and narrowed further along the development process, as new information is available. Narrowed and tightened specifications control the convergence of the design process and the evolution of the design, and in the end, one final well-proven and optimized solution remain (Ward et al., 1995; Ward & Sobek II, 2014).

4.3 Requirement management in concept development

Requirement specifications play central roles in product development and support the direction for solution generation, and provide the normative information for the evaluation. Ulrich and Eppinger (2016) describe requirements specification as one of the key information systems used by the team throughout the development process.

4.3.1 Guidance in the development process

In the context of concept development, the requirement specification is a means to define the initial purpose of the project and expresses what the product must do and fulfill, in a precise, measurable, and detailed way (Ulrich & Eppinger, 2016). In the generic concept development process described in *Section 4.1.2*, requirements are used throughout the process. They are involved in the second step of establishing target specifications and are further used as input to the concept generation phase, where the requirements help to define the solution space and guide the direction of the solutions to be derived. In the end, the requirements are used for evaluating and eliminating concepts in the process of concept selection.

In both point-based and set-based approaches for concept development, the requirements are used for evaluation, but in different ways. In Set-based concurrent engineering the requirements are used to evaluate the sets of concepts as a basis for elimination and convergence towards a final concept. In PB development, the requirements are initially used to select a concept that the team considers to fulfill the requirements the best. Afterward, the requirements are used to evaluate the selected concept, to identify the areas that need further refinement for requirement fulfillment.

Requirement specifications are not set and final from the beginning, but rather continuously evolving throughout the development process as further knowledge and information are available. Having broad targets initially can allow for a wide exploration of the solution space, which is the case in set-based concurrent engineering.

4.3.2 Requirements reflecting different perspectives

The requirements originate from different stakeholders, such as users, end-customers, manufacturing, and marketing. Including several stakeholders' wants in the requirements specification helps to prevent problems arising in later development stages, such as costly and time-consuming product changes. Ulrich and Eppinger (2016) stress the importance of requirements to reflect end-user and customer needs and Cooper (2019) stresses the importance of prevailing a customer focus throughout the development process for product success.

Having a focus and thorough understanding of the customer's needs and wants, the competitive situation, and the market's nature is essential for product success (Cooper, 2019). Strong market orientations leave nothing to chance, a product must satisfy customer's needs to succeed in the marketplace (Mital, Desai, Subramanian, & Mital, 2008). Strong market orientation is important in developing superior products, which is described as a key factor in successful product development (Cooper, 2019; Cooper & Kleinschmidt, 1995; Mital et al., 2008). Superior products can be characterized by the uniqueness of the product, how the product meets customer needs, offer product benefits superior to competitors' products by unique features and attributes, and high product quality perceived by the customer (Cooper, 2019; Mital et al., 2008). Thus, developing superior products requires a thorough understanding of the current and potential competitive landscape, changes in the market, and information about what the people need and want.

In the generic concept development process prescribed by Ulrich and Eppinger (2016), establishing the requirements is sequential to the identification of customer needs, and it involves the translation of user needs into metrics to guide the subsequent steps in the development process. Ulrich and Eppinger (2016) suggest that team members who have not been involved in the identification and translation of customer needs and setting the requirements specification should be familiar with the preceding activities and results, to ensure that the customer perspective is integrated when generating concepts.

4.3.3 Methods for market and customer understanding

A better understanding of the different types of customer and user needs can be achieved by using the Kano model, see *Figure 4.6*. The Kano model distinguishes three types of product requirements that influence customer satisfaction when met (Matzler & Hinterhuber, 1998; Kano, 1984). The Must-be type is the basic criteria of a product that the customer takes for granted. These requirements are not explicitly expressed, but If not fulfilled, the customer will be dissatisfied. Performance types represent the requirements that are explicitly demanded and expected by the customer, and the satisfaction is proportional to the level of fulfillment. Delighters are the requirements that are neither explicitly expressed nor expected by the customer. Fulfillment of these requirements leads to more than proportional satisfaction. If not fulfilled, the customer will neither be satisfied or dissatisfied. Distinguishing the different types of customer and user requirements can support understanding and prioritization of what needs to be addressed in the development from a competitive perspective.

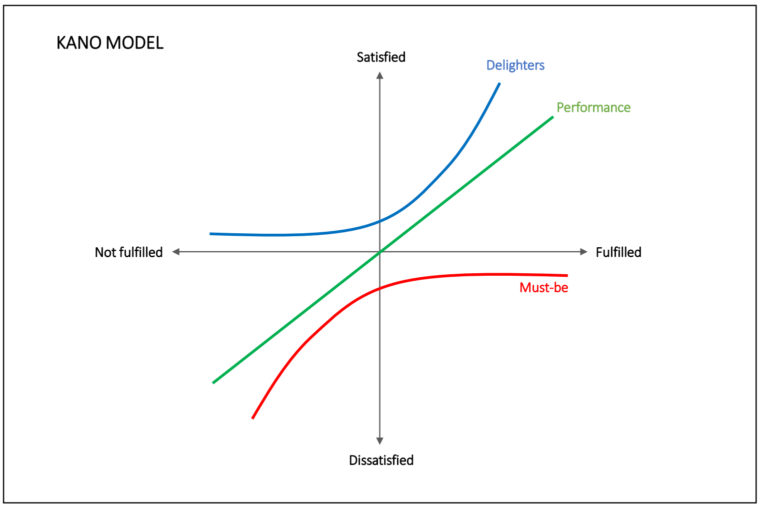

Figure 4.6: The Kano-model (after Matzler and Hinterhuber, 1998)

Requirements specifications can be used to communicate measures for the competitive positioning that has been agreed on before entering the development process. The metrics for competitive positioning require information of competing products on the market, both internal and external, which can be done by conducting a competitive benchmark. It provides a point of reference to measure and judge product quality, and understanding the relationship of new products to competitive products is paramount in determining commercial success (Cooper, 2019; Ulrich & Eppinger, 2016; Otto & Wood, 2000).

4.4 Functional analysis in concept development

Functional analysis is essential in concept development as it facilitates the generation of concepts that address key properties and functions that need to exist in order to develop purposive products. The analysis helps to understand the functions of the product as well as clarifies what and where the problem or challenge that must be handled during the concept development process is. According to Ulrich & Eppinger (2016), an ideal input for functional analysis is a requirements specification.

In concept development, functional analysis can be done in different ways. The fundamental idea of functional analysis is to explain the behavior of a system or a product without expressing any geometry. The goal is often to simplify reality and thereby enable an analysis of how the system or product works as well as what it should do (Müller et al., 2019; Raudberget, 2015).

Several design challenges can tend to be too complex to solve as a single problem and therefore it can be beneficial to divide the problem into simpler sub-problems that are easy to manage and solve in a focused and concentrated way. A complex system or product can consequently be seen as a collection of smaller and more focused design problems. Sometimes a system or product easily can be decomposed into sub-problems but sometimes it can be more difficult, the simpler the system or product the more difficult it may be to decompose it (Ulrich & Eppinger, 2016). Decomposition is most valuable for technical systems or products, but can also add value to simpler and obviously non-technical systems or products (Pimmler & Eppinger, 1994).

When decomposing, either functional or physical elements can be used (Pimmler & Eppinger, 1994). Where a functional element is described with verb + noun and a physical element is described with a physical part, component, or sub-system that realizes the functions of the system or product (Pimmler & Eppinger, 1994; Ulrich & Eppinger, 2016). However, there is a distinct difference between what is most appropriate to use depending on the situation. In a situation where product design is unknown, it is difficult to decompose into physical elements since they are not defined, functional elements are then appropriate. In incremental or derivative projects, when the design is known, it may be easier to decompose into physical elements. When the decomposition is complete, the physical elements can be replaced with functional elements, as functional elements support a more innovative design exploration (Pimmler & Eppinger, 1994). The methods and tools described assume that decomposition takes place in functional elements, however, they can be replaced by physical elements.

There is no correct way to perform a functional analysis. It is suggested that a draft be created first and then refined until a desired result has been achieved (Pimmler & Eppinger, 1994). An advantage of functional analysis is the opportunity to make conscious choices of areas that are considered most critical to the product's success or are likely to benefit from an improvement, thus can be addressed first (Ulrich & Eppinger, 2016).

4.4.1 Methods and tools for functional analysis

Functional analysis through black-box model

One way to perform a functional analysis is through the black-box model, where the function(s) are represented in a box that works on energy, materials, and signal flows. The black-box model is advantageous if a product transform something. The lines that pass through the box represent the transfer and conversion of energy, movement of material as well as control and feedback signals. When using this model, it is advantageous to first define the product's overall function. Then a functional decomposition can be made on the overall function by dividing it into sub-functions. By doing that, a more specific function description of the system or product is obtained, where each sub-function can be handled separately. Sub-functions can be divided into additional sub-functions, thus the decomposition can be repeated until each given sub-function is considered easy to handle. Creating between 3 and 10 sub-functions in the black-box is considered a good rule of thumb (Ulrich & Eppinger, 2016). In *Figure 4.7* the black-box model can be seen.

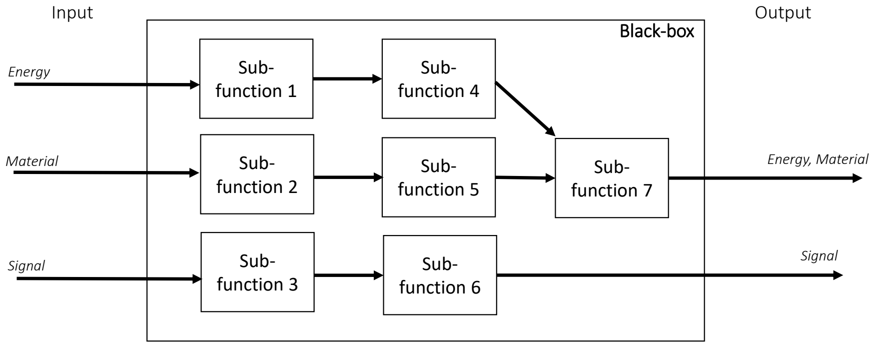

Figure 4.7: The black-box model (after Ulrich and Eppinger, 2016)

Functional analysis through hierarchic tree model

Another way to perform a functional analysis is through a hierarchic function tree model. This model is advantageous if product does not clearly transform something or if it is difficult to identify sub-functions in a chronological order, which is needed when using the black-box model. The hierarchical tree model is a structure where the main function or the overall function is defined at the top. The overall function is then decomposed into subordinate functions, thus placed below the function of the superior in the tree model. Sub-functions can generally be decomposed into additional sub-functions as in the black-box model. The decomposition can be repeated until each sub-function is considered easy to handle (Hubka & Eder, 1988; Pimmler & Eppinger, 1994; Müller et al., 2019). The tree model can be used to describe the product architecture, discover where the most critical problems are located as well as visualize a potential segmentation of a product and thus prepare it for modularization (Müller et al., 2019). In *Figure 4.8* the hierarchic function tree model can be seen.

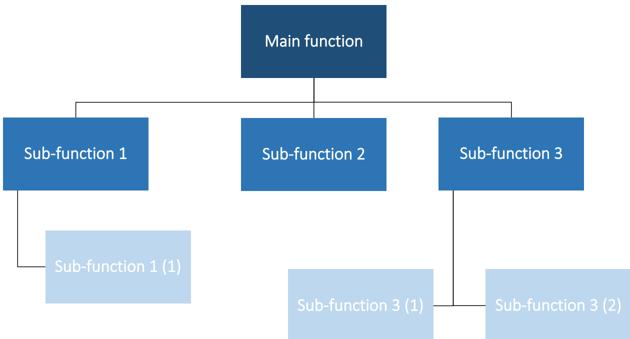

Figure 4.8: The hierarchic function tree model (after Hubka and Eder, 1988)

Functional analysis through function means model

A third way is to use a function means model which is an extended variant of the hierarchical tree model, it is based on the same principle but each subordinate function is determined by a chosen mean (Hubka & Eder, 1988). A mean is explicitly defined as a technical solution to each given function and does not necessarily need to refer to a specific physical part. The description of a mean should be expressed short but sometimes a more comprehensive explanation is needed (Müller et al., 2019). Depending on how many levels the tree model is, the lowest level can possibly describe the system or product at the lowest level of abstraction, which is very close to its geometry (Müller, Siiskonen, & Malmqvist, 2020). In *Figure 4.9* the function means model can be seen.

The main advantage of this model is that it visualizes that the choice of a certain way of achieving a function leads to an additional subordinate function must be presented, to which a new mean must be sought. This entails an understanding that a certain type of mean affects which functions the system or product requires, thus functional requirements emerge (Malmqvist, 1997).

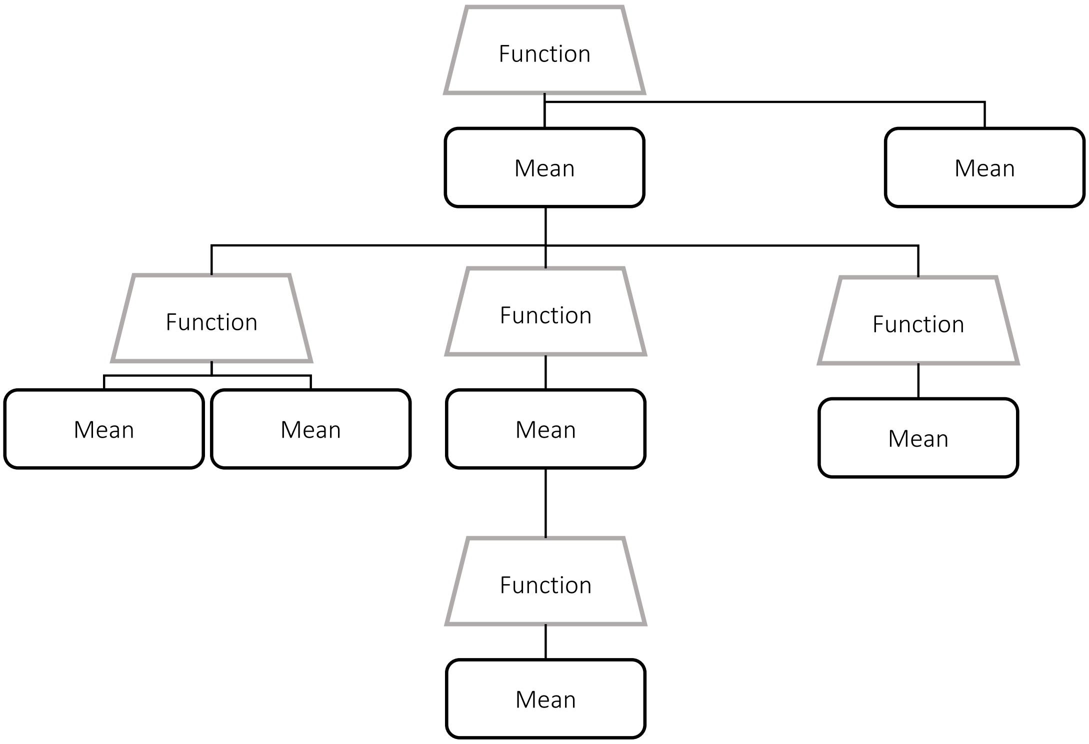

Figure 4.9: The function means tree model (after Müller et al., 2019)

Functional analysis through enhanced function means model

The enhanced function means model is a more comprehensive variant of the function means model where constraints that the means need to adapt to and interactions with other means are included in the model (Müller et al., 2019, 2020). This insertion enables an explanation of underlying requirements for the means and interactions between, which in turn can explain why compromises have been made or need to be made. Thus, the model can contain information about why things are and why things are as they are or need to be (Müller et al., 2020). The enhanced function means tree model is illustrated in *Figure 4.10*.

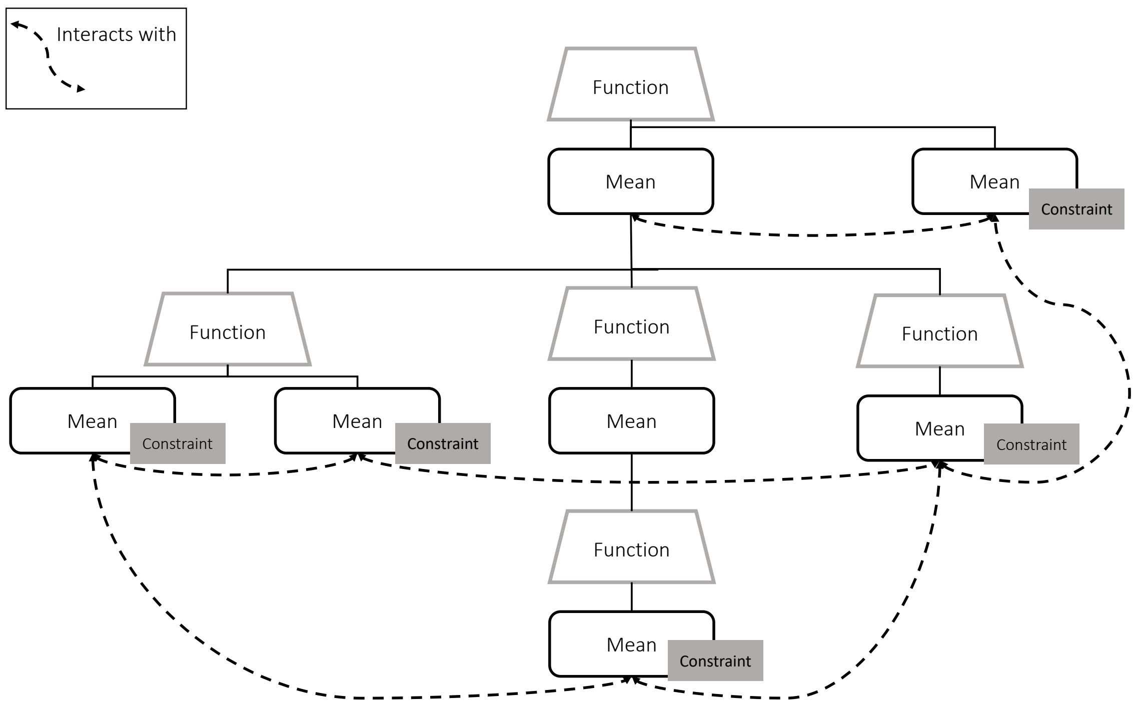

Figure 4.10: The enhanced function means tree model (after Müller et al., 2019)

4.5 Concept generation in concept development

Concept generation is the core of concept development and as the name implies, the purpose is to generate product concept(s). There are two main approaches to generating concepts, either through systematic or creative methods. It should be emphasized that either both approaches or one of them can be used when generating concepts in a project(Yang, 2009). When using systematic methods, it is often very fruitful to make use of creative methods since they facilitate the generation of new ideas and ways of thinking. In the literature, a large number of methods aimed to support concept creation are described. However, there are few studies that have examined the applicability of the methods in industrial settings. As a result of this, there is a lack of recommendations on which methods should be preferred or how to implement them.

The approaches described in *Section 4.2*, Point-based and Set-based relate to concept generation in different ways. When a point-based approach is used, the aim is to generate few concepts while the aim with Set-based is to generate sets of concepts where many alternative concepts are represented. Generating sets of concepts support the exploration of the solution space to a greater extent. In the literature, there is a lack of descriptions for how to generate several alternatives, which can make it difficult to implement a set-based approach. Al-Ashaab et al. (2013) claims that there currently are no clear guidelines in the literature for how to implement a set-based approach in practice. He believes that there is a need for a step-by-step guide that explains tools and methods for generating alternative solutions and how the alternative should be handled throughout the product development process.

4.5.1 Methods for concept generation

The methods that are being mentioned here are primarily used and intended for the development and design of new products. But still, they can be useful when optimizing already developed products or when patents belonging to a competitor have to be evaded (Pahl, Beitz, Feldhusen, & Grote, 2007). This implies that the methods chosen to be used may need to be adapted to and used in accordance with the scope of the project.

Gathering the latest information and knowledge about how the same or similar design problems have been solved can provide inspiration and new perspectives. Searching in literature and among patents, exploring products from competing companies, products within the company, similar products or units where certain sub-functions and parts of the functional structure correspond to those for which a solution is sought may be worthwhile at the beginning of concept generation (Pahl et al., 2007; Ulrich & Eppinger, 2016). Pahl et al. (2007) states that an analysis of existing products can be one of the most important contributions to generating new or improved solutions. Furthermore, Ulrich and Eppinger (2016) describe that interviews with lead users, those who discover needs long before the majority of the market, can be useful in concept generation. In many cases, these users have already come up with solutions to meet their needs, hence inspiration can be taken from them.

4.5.1.1 Systematic concept generation methods

Systematic methods are based on the deliberate generation of solutions step by step. Sub-solutions are generated, which are then combined and constitute total solutions (Pahl et al., 2007). Pahl et al. (2007) claims that systematic methods are discursive bias, where intuition is not excluded but only occurs in individual steps and not influences the execution of the overall task. According to Ulrich and Eppinger (2016), systematic methods enable easier navigation of possible concepts by organizing and synthesizing sub-solutions into total solutions.

Concept creation through combination table

The combination table or often referred as morphological matrix is a systematic method for creating concepts and a way of organizing thinking and guiding a group's creativity (Ulrich & Eppinger, 2016). The basis for the method is the functional analysis (see section *4.4 Functional analysis in concept development*) since the main function needs to be divided into manageable sub-functions. A morphological matrix supports a systematic approach where possible sub-solutions for each given sub-function are generated, which are then combined into total solutions (Pahl et al., 2007). *Figure 4.11* shows the morphological matrix. The idea with a morphological matrix is to systematically generate several total solutions by selecting one sub-solution from each row. When a morphological matrix is used, one should be aware that the number of sub-functions should preferably not exceed three or four to be a practically manageable method (Ulrich & Eppinger, 2016).

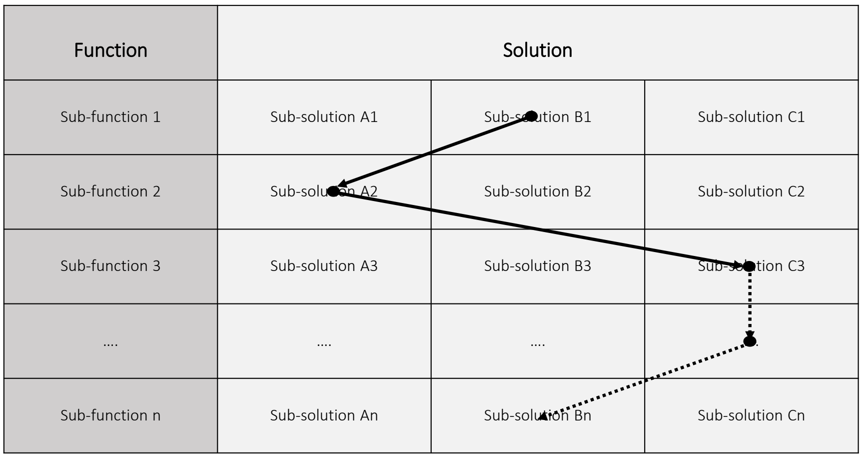

Figure 4.11: The morphological matrix (after Pahl, 2007)

A morphological matrix facilitates the generation of as many fundamentally conceivable solutions to a problem as possible, which is the method's main advantage. However, it should be emphasized that sub-solutions that are unfeasible and/or not compatible with each other should not be combined and the number of combination that needs to be considered could drastically be reduced (Pahl et al., 2007; Ulrich & Eppinger, 2016).

4.5.1.2 Creative concept generation methods

Finding solutions to problems often happens through a humans' intuition, solutions come relatively quickly after a moment of reflection. Creative methods are based on this intuition in humans, where solutions are generated based on a feeling, previous experiences, knowledge, and creativity. According to Pahl et al. (2007), creative methods are considered intuitive bias and many of the methods involve group dynamics with loose structures to facilitate creativity and innovation. Below, Brainstorming, the 6-3-5 method, Gallery method, which are three creative methods will be described.

Concept creation through brainstorming
Brainstorming is a method used to generate many new ideas in a group of open-minded participants, where all thoughts and ideas are allowed to emerge. To get the most out of a brainstorming session, it is important how the group is composed, optimal behavior of participants has clarified as well as that a leader has been appointed. The group should consist of five to 15 people, fewer than five constitute a spectrum of opinions and experiences, and more than 15 increase the risk of individual passivity. Among the participants, as many fields as possible should be represented. The leader is responsible for the invitation, composition, duration, evaluation, and ensuring that the atmosphere remains free and easy. During the session, all participants mustn't judge or reject ideas that are considered unrealistic, stupid, or already tried. All ideas should be written down, recorded, or sketched. The session duration should be between 30

to 45 minutes. The last thing that happens is that the ideas are examined together with the whole group to avoid possible misunderstandings or one-sided interpretations. New and improved ideas can then also be expressed.

According to Pahl et al. (2007), Brainstorming is very useful for generating totally new ideas and ways of thinking, but ready-made solutions that are both technically or financially feasible can not be expected through just a brainstorming session.

Concept creation through 6-3-5 method
The 6-3-5 method is a developed version of Brainstorming. It starts with that six participants familiarize themselves with the task and then each of them writes down three solutions which they then pass on to the respective neighbor. The solutions that each participant receives are further developed, this continues until the solutions return to the original creator and have been processed by the other five participants (Pahl et al., 2007), hence the name 6-3-5 method.

The main advantages over brainstorming are that the 6-3-5 method supports a systematic way of developing ideas and in addition, it is possible to follow the development of an idea. The 6-3-5 method is not an overt group activity and each participant generates ideas in their solitude, thus there is a risk of reduced creativity among the participants (Pahl et al., 2007).

Concept creation through gallery method
Another creative method is the gallery method and is a combination of group and individual activities, where all participants work with the same problem but sketch solutions on separate sheets of paper. All sheets are then hung on a wall, where the group can observe and discuss them together. The purpose is to identify complementary or improved ideas, as well as completely new ones. The insights from the discussions are then further developed individually and all modified or new ideas are hung on the wall. The last activity is the selection, where promising solutions are identified (Pahl et al., 2007).

The gallery method has the following advantages; group work takes place without unduly lengthy discussions, a large number of ideas can easily be placed on the wall, sketches enable efficient exchange of ideas, identification of who did what can easily be traced as well as stored (Pahl et al., 2007; Ulrich & Eppinger, 2016).

4.6 Decision-making in concept development

A central part of concept development is the process of decision-making and selection of concepts for further investigation, testing, or development (Ulrich & Eppinger, 2016; Mattson & Sorensen, 2019). The process of decision-making can be supported by different methods that aim to identify a concept that fulfills users', customers', and other stakeholders' needs to select the most promising product concept to spend the resources on (Raudberget, 2015; Ulrich & Eppinger, 2016). However, in the concept development stage sufficiently high level of detailed information of the product concepts is not obtained when a decision must be made, which can make the process of decision-making very difficult.

4.6.1 Decision points

Depending on the approach that is used for undertaking concept development work, the decision point of concept selection differs. For the set-based concurrent engineering approach, the decision point is delayed until enough information is available, in opposite to the point-based approach, where the decision for concept selection is made early in the process when knowledge is incomplete (Ward & Sobek II, 2014; Morgan & Liker, 2006). In set-based concurrent engineering, the decision-making process is not a process for selecting the most promising concept, but rather a process of deciding on rejection of concepts, leading towards convergence to a final concept superior to others. Thus, the focus is to eliminate concepts that are proven unfeasible according to relevant criteria at the current state of development, rather than selecting the most promising concept based on incomplete information (Raudberget, 2015).

Delaying the decision point, as done in set-based concurrent engineering, can be considered to have a negative impact on development speed and increase development cost, and at the same time be considered as very efficient. Ward and Sobek (2014) claim that the process of considering many alternatives and delaying the decision point increases the speed of the development process because learnings and knowledge that has been built helps to prevent costly and time-consuming late-cycle design changes.

4.6.2 Methods for decision-making

Different methods that support the decision-making process exists, *Table 4.2*. The methods vary in their effectiveness and may not be suitable for making adequate decisions. Decision matrices are found to be effective methods for a structured evaluation and decision-making process and will be further described in this section.

Table 4.2: Methods supporting the decision process (Ulrich and Eppinger, 2016)

Methods supporting the concept decision process	
External decision:	Concepts are turned over to the customer, client or some other external entity for selection.
Product champion:	An influential member of the product development team chooses a concept based on personal preference.
Intuition:	The concept is chosen by its feel. Explicit criteria or trade-offs are not used. The concept just seems better.
Multivoting:	Each member of the team votes for several concepts. The concept with the most votes is selected.
Web-based survey:	Using an online survey tool, each concept is rated by many people to find the best ones.
Pros and cons:	The team lists the strenghts and weaknesses of each concept and makes a choice based upon group opinion
Prototype and test:	The organization build and tests prototypes of each concept, making a selection based upon test data.
Decision matrices:	The team rates each concept against prescribed selection criteria.

4.6.2.1 Decision matrices

Decision matrices are structured methods that provide several benefits; support concurrent evaluation of several alternatives, effectively integrates different perspectives, documentation of decision process, and provide a good overview of a great amount of information (Ulrich & Eppinger, 2016; Mattson & Sorensen, 2019). Different matrices can be used for different purposes and this section briefly described three different methods; Concept selection matrix, Elimination matrix, and Pugh-matrix.

Concept selection matrix

A concept selection matrix is a tool that helps to catalog and organize collected thoughts, ideas, and solutions (Schipper & Swets, 2012). The matrix is beneficial for the evaluation of many ideas at once and provides a better picture of deficiencies and superior solutions. It is also working as a historical record for future reference of how concepts fulfill certain attributes. The generated concepts are evaluated and rated against key attributes that consider different types of wants, such as organizational, customer, or any other wants necessary to be included or fulfilled by the product to be developed. Schipper and Swets (2012) describe that the concept selection matrix is a great tool to include in the lean product development toolbox, for use in the early stages of development to capture and compare ideas.

Elimination matrix

An Elimination matrix is a decision method used for the removal of disqualified solutions. Solutions are evaluated concerning the fulfillment of requirements and other criteria considering general aspects such as reasonable cost, fit into the product portfolio, and if it is realizable. A solution is considered disqualified if it does not fulfill the requirements and criteria. The method may constitute a strong filter and is suitable to use as an initial step in the decision-making process if a comprehensive number of alternatives are to be evaluated.

Pugh-matrix

The Pugh-matrix is a well-known method for evaluation, with the aim to compare and select the most promising concept among a set of alternatives (Pugh, 1990). The evaluation with Pugh-matrix is relative using a datum, a reference solution, to which the alternatives are compared as better (+), same (S), or worse (-) than the datum with respect to different criteria. The results from the comparison provide a base for discussion of the different concepts' strengths and weaknesses and can serve as guidelines for improvements of the concepts (Ulrich & Eppinger, 2016; Raudberget, 2015). An important feature of the method is the relative comparison between individual properties of the design since it is easier for humans to compare a solution to a datum than it is to evaluate a numerical score. Traditionally, the method aims to select concepts, but the method also allows to be used for the elimination of concepts. Ström, Raudberget and Gustafsson (2016) describe how the methods can be used in projects conducted with a set-based approach, by an inverse Pugh-matrix used to eliminate concepts in the process of narrowing sets of alternatives.

4.7 Summary of Theoretical frame of reference

Chapter 4 has presented a theoretical frame of reference relevant to the scope of the project in terms of design theory and methodology related to concept development, two main approaches to concept development, as well as requirement management, functional analysis, concept generation, and decision-making in concept development.

The design theory and methodology related to concept development describes a generic product development process, to put concept development into context. Further, a generic concept development process is described. For the two main approaches to concept development, point-based and set-based are presented with descriptions of their strength and weaknesses. The later sections in the chapter, concerning requirements management, functional analysis, concept generation, and decision-making in concept development, present the purpose and roles of each respective area within concept development accompanied by methods and tools.

The theoretical frame of reference highlights important aspects to consider for the development of the Toolbox and methods and tools that serve as the basis for the proposed methodology. Further, it serves as a reference basis for analyzing and discussing findings.

5 Results

This chapter presents the results of this thesis. Firstly, the findings related to the current situation at Husqvarna Construction Products are presented. Lastly, the results of the creation process of the Concept Development Toolbox are presented.

5.1 Current situation at Husqvarna Construction Products

The interviews that were conducted during the second phase of our research process resulted in different findings related to the current situation at Husqvarna Construction Products. In this section, the findings are presented following four significant themes: Approach to concept development, Frontloading, Integration of perspectives, and Documentation.

5.1.1 Approach to concept development

Husqvarna Construction Products does not have one common approach to concept development, currently, it is up to the individuals in each project to decide how to conduct the concept development work. The interviews made it evident that concept development is approached in several different ways and there is a lack of consistent execution, choice of tools and methods, and how and where the decision-making take place.

5.1.1.1 Efforts for structured development

At an organizational level, there is a willingness to implement a more structured concept development approach. This has been done by encouraging the employees to use a more structured approach to concept development. A concrete example of this is the instructions in the Product Creation Process where the employees are encouraged to use set-based concurrent engineering when concept development is carried out.

Furthermore, an inspirational lecture about set-based concurrent engineering is held regularly. The aim of the lecture is to create an understanding of the approach and associated benefits. During the lecture, a practical example of how to apply the approach in a concept development project is presented. However, the example is based on a flashlight and not a Husqvarna product, which several interviewees pointed out as a disadvantage. They mentioned that functional analysis, generation, and evaluation of concepts look very easy when the example is demonstrated because it is done on a simple product. The products at Husqvarna Construction Products are much more complex and the majority of the interviewees do not know how to practically use set-based concurrent engineering in concept development projects. However, some interviewees are in favor of using set-based concurrent engineering.

During the interviews, it became known that there is a template available as support when using set-based concurrent engineering in concept development projects. However, it turned out that not all interviewees were aware of the existence of the template.

5.1.1.2 Different approaches

Point-based approaches are common for concept development work conducted at Husqvarna Construction Products, though the term point-based was not explicitly used by the interviewees. It was described that concept development work often begins with a requirement specification from product management as input, followed by a session of generating a few alternative ideas and then quickly selecting the idea that was considered the best, for further development and evaluation.

It was described that the activity of idea generation for concepts usually is not performed thoroughly or systematically, and rarely considers the exploration of different alternatives. Hence, the generated concepts are usually based on solutions that the development team already has the experience and knowledge of. The decision of concept is similar to theoretically described methods presented in section *4.2*, referred to as intuition- and product champion method. The selection of concepts is made based on feeling of the ones that seem the best or based on personal preference by an influential member of the team.

Some interviewees had experienced working with set-based approaches, which included working with the set-based concurrent engineering approach and template available at Husqvarna Construction Products. It has received both positive and negative feedback. Some explained it to be too complex to follow and did not really understand the purpose or value of it, while others were more enthusiastic about it and had received great results from following the approach. The part of generating sets of concepts and perform evaluations for each concept was mentioned too comprehensive for large and complex systems, but well suited to use for sub-systems.

5.1.1.3 Methods and tools

The Product Creation Process defines the deliverable from concept development but leaves out information on how to achieve them. Different tools and methods are, in some cases, suggested in the Product Creation Process, but there are no clear instructions or guidance explaining how to use them. This presumes that the people working with concept development either have previous knowledge and experience or that time is spent on familiarizing themselves with the suggested methods and tools.

Depending on previous experience and knowledge, some are more familiar to established methods and tools that support concept development execution and make use of it in their projects, e.g., personas was used as a tool to get a better understanding of the customer. It is also evident that different established methods and tools are being used, without consideration of it as a tool or method. E.g., investigating competitors' products to get a better understanding of the market is done, but without considering it to be the method of competitive benchmark. Instead, it is considered to be an activity that is necessary to perform and is done without reflecting.

Among the engineers at Husqvarna Construction Products, it is evident that there are different levels of knowledge and experience connected to concept development methods and tools. Depending on that level, methods and tools can be perceived as complex and difficult to use in concept development work. If there is no previous knowledge and/or experience about certain methods and tools, it takes time and effort to get familiar with them, time and effort that not exist when there is a tight time plan. It is mentioned that there is a reluctance to use methods and tools that seem complex and/or time-consuming. Furthermore, it is mentioned that it is desirable regardless of the level of knowledge and experience, that the methods and tools should be lean and pragmatic.

5.1.1.4 Adaptation of processes

Different experience and background of working with concept development are evident, some prefer to work structured and with defined methods, while others preferred to do it the way they have always done it. It was mentioned throughout the interviews the importance of having processes that allow for adaptation, it should work as a support for execution and not something that one must follow strictly. Otherwise, it could lead to resistance to work accordingly to the prescribed process. The expressed need for process adaptation also relates to project type, since different types of projects require to be approached differently. As for Husqvarna Construction Products, it was mentioned that most of their concept development projects considered refinements of already existing products where either new opportunities or problems have been identified. The input to those projects are requirements, which corresponds to project types that are market-pull or customized-driven. However, sometimes projects of new technologies or breakthrough products occur which then corresponds to project types technology-push.

5.1.2 Frontloading

Tight time plans and demands to deliver results quickly in projects have been highlighted by certain interviewees as a major reason for not working more structured and extensively with concept development and associated activities. There is simply no time to use methods and tools to investigate and determine the challenge of the project, understand the system's functions, search for alternative solutions and possibilities. Instead, the majority of R&D teams choose the first best solution they come up with in order to deliver results within the time plan.

However, the view of tight time plans not allowing to work with structured approaches and more extensively, is not shared by everyone. Others claim that it is acceptable to overrun time plans by working more structured and extensively in the early phases of development projects if it results in a better outcome. Thus, there is a discrepancy in the views of what drives concept development work; keeping time plans or delivering better results. Reflecting on the scope of this master thesis, the project aims to improve the execution of the concept development projects, rather than analyzing the organizational views of front-end activities and the creation of time plans during concept development projects.

It is mentioned by several interviewees that problems often arise in the later stages of the product development process. These problems can often be related to decisions made in earlier stages. At the moment, there are several employees who spend a lot of time solving problems and "putting out fires", this is very time-consuming and prevents the employees from performing the tasks they are supposed to do. In addition, problems discovered in the later stages of the product development process can affect project lead times. Some interviewees think that too much time is spent on "putting out fires" in the later stages and think that this could have been avoided by prioritizing front-end activities.

5.1.3 Integration of perspectives

Through the interviews, it was found that the integration of different types of perspectives is deficient during the concept development work. Some of the findings are outside of the scope of the project, but considered significant to mention.

5.1.3.1 Broad system perspective

It was mentioned during the interviews that concept development usually is too narrow and product-specific, in the sense that the solution to be developed is not considered for other products, product categories, or systems. Some people claimed that there is a lack of collaboration between different organizational segments at Husqvarna Construction Products which has led to similar solutions being developed in different projects. Having a broader perspective and consider other areas and products before initiating a concept development project could have positive effects on resource efficiency and the development of robust solutions. Facilitating collaboration between different segments is outside the scope of this master thesis, as the project aims to improve the execution of concept development projects.

5.1.3.2 Engineering domains

Another challenge discovered was the deficient consideration of different engineering domains during concept development. The products developed at Husqvarna Construction Products consider different engineering domains, such as mechanical, software- and connectivity. Mechanical design often requires longer development lead times in comparison to software, where testing and changes can be done rather quickly. This has led to a situation where the software domain is often considered in later stages in the concept development process. Different engineering domains have different requirements and constraints on the solution and considerations to those need to be taken initially in a project to reduce the risk of problems arising in later stages.

5.1.3.3 User focus

Several interviewees brought up the problem of having too little focus on the end-user of the intended solution to be developed throughout the development project. A concept development project begins with inputs from product management in the form of a requirements specification. Often, the specification consists of requirements that are too technical or product-specific, making it difficult for the R&D team to trace the requirements to the actual needs of the user. This results in deficient integration of user perspective in the concept development process, which is essential to incorporate since Husqvarna Construction Products claims to develop products with the user in focus. In the theoretical chapter, section *4.3.2*, the importance of a user and customer focus prevails throughout the development process for product success is described. Some interviewees described that they put in efforts to build their own understanding of the user by testing the product from a user perspective by considering the routine of usage and the feeling of the product, not just focusing on the functional aspects. Another interviewee mentioned that they involved Global Design to create personas for the users, as an effort to incorporate a stronger user focus in the development project.

5.1.4 Documentation

Currently, there is no standardized or obligatory way of documenting the execution, decision points, and results during concept development at Husqvarna Construction Products. This means that it is up to the individuals in each project to document what they think is necessary and thus documentation takes place in different ways and to different degrees. When there is no defined or standardized way for documentation during a concept development project, some find it difficult to know what is necessary to document and neglects it. It is further explained that deficient documentation also can be caused by not giving documentation high priority when there is time pressure in projects or when it is not compulsory to document.

5.1.4.1 Information and knowledge capture

It is a widespread view of documentation and the necessity of it in concept development. Some interviewees only consider documentation as time-consuming and non-value-adding because the benefit of documenting information and knowledge that they already have is not evident. Concerning this, there is a perception among some that Husqvarna Construction Products relies heavily on the individuals within the company who carry important information and knowledge about the products they develop.

Others believe that documentation is an absolute necessity, partly for the traceability of certain decisions but also an opportunity to capture information and knowledge created during a project that can be reused in other projects and to create design guidelines. Documentation is specifically pointed out as important for products from company acquisitions. History of company acquisitions means that a thorough understanding and knowledge of prior development of certain products might be missed internally at Husqvarna Construction Products. Hence, there is a need to capture knowledge and create a knowledge bank for those products.

A project that could have benefited from documentation was mentioned in the interviews, to exemplify the need for information and knowledge capture in concept development. Late in a product development project, in the New Product Development phase, problems with the product emerged and it was found that the chosen product concept was not an appropriate selection. This led to discussions regarding the basis and reasons for the concept selection and if any other alternative concepts were considered. Due to a lack of documentation and recollection of the executed concept development work, it was problematic to find the answers to the questions that were raised.

5.1.4.2 Means for communication

The aspect of using documentation as a means for communication of the project is mentioned during the interviews. Unstructured documentation or lack of documentation during concept development makes communication about the project's status and results at meetings more difficult. Some believe that Husqvarna Construction Products could benefit from implementing a more structured and mandatory way of documenting certain aspects during concept development activities, specifically decision-points, to ease communication of projects. What is documented can to some extent be used as visual support at meetings, for that purpose it is important that what is documented is short and concise, preferably in a table and with colors and figures instead of a report with comprehensive amount of written information.

5.1.4.3 Storage and accessibility

An aspect that some interviewees have mentioned is access and storage of the documentation created during concept development projects. Today, there is no common or defined storage location for documentation of information concerning results and decision points from concept development. It is mentioned that the documentation is stored on the employees' computers, via e-mail conversations, in various cloud services, or other ways. This is mentioned as a problem as time must be spent either searching for the knowledge created in previous projects or re-creating and gathering the same knowledge again, which can affect efficiency. However, this master thesis does not comprise the accessibility- and storage aspect of the documents created during concept development projects and will not be addressed further.

5.2 Creation of Concept Development Toolbox

This section presents the results of the Concept Development Toolbox developed for Husqvarna Construction Products to support a purposive and pragmatic way of working with concept development. The Toolbox consists of a Handbook and Template that comprise a concept development methodology adapted to the needs at Husqvarna Construction Products. The Toolbox was developed through an iterative process and included involvements of candidates from Husqvarna Construction Products. The first part outlines points of departure for the development of the Concept Development Toolbox. While the second part describes how the Toolbox has been developed, including the proposition of methodology and the design of the Toolbox.

5.2.1 Points of departure

The Concept Development Toolbox aims to support structured and pragmatic concept development execution, by presenting a concept development design methodology that is derived from theoretically established methodologies adapted to the current situation at Husqvarna Construction Products. Hence, the creation process of the Toolbox has comprised the work of proposing a methodology as well as designing a Toolbox, that comprises that methodology. An analysis of the theoretical findings in chapter *4* and the empirical findings of the current situation at Husqvarna Construction Products in section *5.1*, outlaid points of departure for the creation process. *Table 5.1* presents important points of the departure assigned for the methodology and Toolbox, respectively.

Table 5.1: Points of departure

Points of departure
Methodology
Prescribe activities for how to go from requirements to solution
Provide methods and tools for functional analysis, concept generation and concept decision-making
Facilitate consideration of several alternative solutions.
Support end-user focused concept development
Integrate different perspectives
Allow for adaptation, to be applicable for different project types
Toolbox
Support usage without prior knowledge and experience of concept development design methodologies
Lean content
Support practial application of the methodology
User-friendly, considering format and design
Support purposive documentation
Provide visual means to support communication of project

5.2.2 Proposition of methodology

The proposed methodology is a result of a synthesis process, where theoretical design methodologies have been adapted to the situation at Husqvarna Construction Products, based on empirical findings from interviews and new insights raised during the iterative creation process. The methodology comprises methods and tools that are well-proven in theory and internal methods and tools that are currently used at Husqvarna Construction Products.

The methodology is presented in four phases that prescribe activities of how to go from requirements to solutions, see *Figure 5.1*. Presenting the methodology in four phases supports structured, focused, and purposive execution. Each phase has a distinguished purpose and comprises associated methods and tools for purposive development execution. It needs to be emphasized that the methodology allows for the usage of other methods and tools that are deemed more suitable by the user, as long as the purpose of each phase is achieved.

Figure 5.1: The proposition of methodology defined by four phases

The core of the methodology is to explore broadly, consider sets of solutions, and gradually narrow the sets by elimination of solutions, leading to convergence towards a final concept. It is derived from the set-based approach, which supports considerations of several alternative solutions and prevents the appearance of late changes in the product development process, which was highlighted as a severe issue in their current development process.

5.2.2.1 Phase 1: Understanding the Challenge

In order to develop an innovative and competitive product, it is important to have sufficient knowledge about the challenge and problem situation, the competitive landscape, market and user needs as well as targets for the intended product. At the beginning of a concept development project, it is important that everyone in the team has a common understanding of the challenge, what is to be developed, and what targets the project has. This phase aims to create this understanding and guide the project in a purposeful direction.

The generic concept development process describes the importance of performing activities to identify customer needs and establish the target specification early in a concept development project. Identifying customers' needs early allows the development team to take their needs into account early in the development before product design has been established. To understand what the product must do to fulfill the customers' needs, they need to be translated into technical terms, which will end up in a target specification.

In this phase, the activities that the generic concept development process advocates that one should do have been collected. The phase is named Understand the Challenge and four tools are presented, which aim to serve the purpose of the phase. The expected outcome of this phase is a concretized problem and key-requirements.

This phase was originally called *Understanding the Problem* but was changed to *Understanding the Challenge*, because the majority of candidates from Husqvarna Construction Products considered it more suitable. The reason for this is that engineers who execute concept development projects at low TRL do not usually work with problems, but instead investigate opportunities and challenges. Thus, the change of name was considered an appropriate measure to make it more relatable to people.

Problem description

A problem description will help the team to concretize the problem or challenge by considering the problem itself and its context. When the team formulates a problem description, there is an opportunity to discuss, reflect and analyze the problem to be solved. This allows all members to create a common understanding but also guides upcoming activities.

In order to create a comprehensive and concrete description, one can think about where and when the problem is relevant, how it happens, if there are any specific challenges, and who the customer or user of the solution could be. In a few concept development projects at Husqvarna Construction Products, similar descriptions have been made. The description was then created by the team, and the overall target of the project was described in 1-2 sentences. The problem description proposed in this phase should provide a more comprehensive understanding, where both the problem itself, its context, and potential customers and users can be analyzed.

Competitive benchmark
Competitive benchmarks can be used to create an understanding of the competitors' products and technologies as well as your competitive position. By understanding the competitors' products and what is available in the market for the customer, there is a great opportunity to develop superior products and gain a strong market position. Benchmark is a beneficial tool for identifying distinctive features of products in a structured way, understanding why certain products are successful and re-use some of the successful properties in the product that intends to be developed. A benchmark can provide points of reference to measure and judge the product quality, value, or performance of the product that intends to be developed. Points of reference, values, and other relevant aspects found through a benchmark should be reflected in key-requirements. In addition, benchmarking can be used in order to find inspiration on how the same or similar problems have been solved and ideas that have arisen can be used in the third phase where concept generation takes place.

Benchmarking is an established tool that many engineers at Husqvarna Construction Products are familiar with. In cases where a benchmark is performed at Husqvarna Construction Products, it is performed in the beginning of the concept development process to get an understanding of how similar problems are solved today and how competitors solve the problem.

Voice of customer with Kano model
In order to develop competitive products it is crucial that the development team focus on the market and user, the focus should prevail throughout the entire concept development project. Considerations of the market and user needs must be taken before the product design has been decided. So, before starting developing it is important that everyone within the team actually understands the market and user. This activity aims consideration and reflection of the market and the user.

This activity should help the RD team and the project manager to involve market and user perspectives in the upcoming activities and phases. It does not include any collection of new user data to derive users' needs, but rather the aim is to enforce reflection on the existing data that the product manager and/or global design has already collected. Husqvarna Construction Products states that they develop and sell user-centered products. To ensure that user-centered products are developed, there must be a user focus throughout the development process.

The interviews made it evident that there is a need for having a greater user focus when developing products. During the evaluation process, one of the candidates mentioned that the Kano-model could be an appropriate tool to make use of in order to reflect on the users and their related needs.The tool had previously been used in a concept development project on the initiative of the engineers and led to an increased user understanding.

Involving market and user perspectives early in the concept development process can help discover and determine unmet needs. With the help of the Kano model, the team can distinguish between different types of user needs and thus aim to satisfy the needs in the categories of *performance* and *delighters* and ensure that *must-be* needs are satisfied by the product. All relevant needs identified in this activity should be reflected in key-requirements.

Key-requirements
The phase ends with a compilation of key-requirements, specifying what needs to be addressed during the development. Key-requirements bring clarity to the task and guide the project in the right direction, and in the end, they are used as criteria for concept evaluation and elimination.

The key-requirements should consider the requirements specification provided by the product manager, the outcome from competitive benchmarking, the voice of the customer with the Kano model and other relevant aspects. The key-requirements must reflect different stakeholders, by documenting why or whom it is derived from, it is possible to keep track of which stakeholders are reflected in the key requirements. Key-requirements should be revisited throughout the whole concept development process, either new ones can be added or old ones can be refined when new information and knowledge is available.

Key-requirements consist of items, in this case, both requirements and wishes. Both key-requirements and items have been derived from Husqvarna Construction Products, which are the terms they use and adapted to suit their corporate language.

Due to the fact that those who have created the initial requirements specification are not part of the concept development team, it is essential that the team reviews the specification they have received and compiles the items that are interesting for the project.

5.2.2.2 Phase 2: System- and Function Analysis

The second phase serves the purpose of identifying focus areas and understanding product functionality to support solution space exploration. The phase is divided into two segments, system breakdown, and functional breakdown. Both segments include product decomposition but are differentiated by decomposition comprising either physical or functional elements. Decomposing a system is a method for breaking down a complex problem into more easily managed sub-problems, to solve in a focused and concentrated way. The outcome of the system breakdown outlays the focus areas needed to be addressed in the functional breakdown, and the total outcome of this phase is a system- and functional description.

System breakdown
System breakdown aims to identify critical areas that need further focus and development, by the decomposition of a system into physical elements. This was requested, by the candidates from Husqvarna Construction Products, to be performed before the functional analysis. The reason behind it is because, at Husqvarna Construction Products, the concept development projects usually derive from already existing products, described as the project type of customized products in section *4.1.1.1*. Hence, the product structure and the parts of the system are known, and it is easier to begin a

product decomposition by describing it by the known physical elements.

However, sometimes it is not appropriate to perform a system breakdown preceding the functional analysis. For projects concerning products or solutions that are completely new, where the system or product structure is unknown, functional decomposition might be more suitable as a first step.

Decomposing systems into sub-systems supports the identification of areas that are directly affected by the problem that the development team is addressing in the project. Having the system decomposed also helps to perform TRL assessments, to identify the critical areas that need further focus and the areas that can be carried over from existing solutions. The identified critical areas are what needs to be addressed in the upcoming development activities. The tool presented for the activity of system breakdown is called Goal mind map, which is a tool that is internally used at Husqvarna Construction Products. It is a tool that supports visualization of the decomposed systems, the critical areas, and the elements that will be carried over.

Another request that appeared during the iterative creation process was to include the activity of assembling attributes for the defined critical areas. The key-requirements defined in the first phase are addressing the whole project, hence it necessary to compile the different attributes that are directly associated with each identified critical focus area. The attribute can be items from key-requirements, or other items concerning relevant aspects needed to be considered for the specific area, e.g., constraints such as the available space for a solution. Attributes can be integrated into the decision-making process.

Functional breakdown

The functional breakdown aims to provide an understanding of the intended behavior of the system without expressing any geometry or design solution, to support systematic concept generation in the next phase. If critical areas were identified from the system breakdown, the functional breakdown is performed for each identified critical area. Otherwise, a functional breakdown can be performed directly for the defined problem or challenge.

Functional decompositions are abstract representations of the product and its intended behavior. Described in theory, functional decomposition is a method that supports the exploration of more innovative solutions in the concept creation phase. It facilitates consideration and identification of different ways to solve a function, which Husqvarna Construction Products currently are struggling to do during the conceptual design phase. Functional decomposition is usually described as an initial part of concept generation, but this proposed methodology defines it as an own phase, based on that this activity needs to be emphasized at Husqvarna Construction Products.

The hierarchical tree is the tool presented for the functional breakdown in this methodology, due to its simplicity. Other tools, such as the enhanced function means modeling, were proposed during the iterative creation process but excluded since most of the candidates considered it too complex and comprehensive. Further, solutions should not be considered until the next phase of concept generation, hence function means-modeling is not suitable during this phase since it can lead to solutions being considered when defining means for the functions.

5.2.2.3 Phase 3: Concept Generation

The third phase serves the purpose of exploring the solution space by generating sets of concepts. The phase is divided into two activities, sub-solution generation, and concept creation. The phase begins with sub-solutions generation, where the aim is to freely generate sub-solutions to each sub-function, which is derived from the functional breakdown from the previous phase. Continues with concept creation where the sub-solutions are combined into total solutions. The outcome of this phase is several alternative concepts, minimum of three. The reason why there is a minimum of three is to indicate that at least a couple of alternative concepts must be created in this phase. Otherwise, the purpose of exploring the solution space by generating sets of concepts is not served.

This phase focuses on presenting a systematic concept generation method and thus no methods for creative idea generation are presented. It was described that some engineers may find it difficult working with methods for freely concept generation, as it can be perceived as too abstract. They need some form of guidance or boundaries for the concept generation activity, which a systematic method can provide. Furthermore, the content of each phase should be lean and no one mentioned during the iterative creative process that they needed explanations on how creative methods should be performed. The sub-solution generation activity, however, encourages the user to make use of brainstorming, analysis of competitors' products as well as search in literature.

Sub-solution generation

The sub-solutions generation aims to freely generate sub-solutions to each sub-function, which is derived from the functional breakdown. Generating sub-solutions to sub-problems is beneficial because it helps solve problems in a focused way. The sub-problems are presented as functional elements, named sub-functions. In this activity, a combination matrix is used, where sub-solutions from the functional breakdown are inserted.

In the templates available at Husqvarna Construction Products, it was evident that they had been using a combination matrix to generate sub-solutions and then combine them into concepts. Thus, those who have used the templates should be familiar with the method.

Sub-solution generation can be done to different degrees of detail and can also be an iterative process. First, different classes or categories of sub-solutions can be generated, which enables a broad exploration of the solution space and works well when you are at low TRL levels and aims to explore different sub-solutions. The process can then be iterated by examining detailed sub-solutions within each category, which will create more detailed concepts in the next activity.

A request that arose during the iterative creation process was to enable a preliminary assessment of each sub-solution against key requirements or attributes, as well as organizational readiness. It was considered that the preliminary assessment would provide support for the identification of clearly inferior or unfeasible sub-solutions.

Concept creation
Concept creation aims to create concepts by systematically combining sub-solutions into total solutions in a combination matrix. This method is used to generate as many conceivable concepts as possible, to create a set of concepts.

In many concept development projects, all conceivable concepts will not be generated in the matrix. Combinations that are clearly incompatible or inferior will be excluded, due to the fact that there is not worth investigating, which relates to the set-based approach of narrowing the sets of solution. However, it is important to comment on the reasons for exclusion as well as ensure that the generated concepts represent different principles or classes of concepts. It is important to generate several alternative concepts, it does not have to be the "best" combination or a combination that is likely to be the final, what is considered to be the "best" or final combination might not be true and it requires further evaluation to make those judgments.

Considering how Husqvarna Construction Products develops its products by selecting critical areas of a product to be further developed, a combination matrix is advantageous. The combination matrix can first be used for each critical sub-system and create a set of concepts for each. Then the matrix can be used to combine those sets of concepts for different critical sub-systems, resulting in a set of concepts addressing several critical areas.

5.2.2.4 Phase 4: Concept Evaluation & Elimination

The purpose of the fourth and final phase presented in the methodology is to systematically evaluate and eliminate concepts based on knowledge to converge on the final concept(s). It supports a decision-making process, in which the decision of final concepts is a result of an elimination process rather than a selection process.

It was found through the empirical findings that one of the severe issues with the current approach to concept development is that the decision-point of concept usually takes place early on when sufficient knowledge is not yet obtained and without considering alternative options. Hence, this methodology proposes that the generated alternative concepts should be evaluated and systematically narrowed by elimination if deemed unfeasible or inferior, leading to convergence towards a final concept. The emphasis is to make decisions based on knowledge and facts.

Different perspectives can effectively be integrated during the decision-making process, through reflection in the evaluation criteria used throughout the decision-making process. The evaluation criteria must reflect the key-requirements defined in the first phase, attributes from the second phase, and other relevant items needed to be addressed for decision-making.

Concept comparison matrix
Decision matrices are effective tools that support systematic evaluation and elimination of concepts. As described in the literature, different matrices can be found with distinguished purposes. For this methodology, a concept comparison matrix is presented as the tool to support the evaluation and decision-making process. A concept comparison matrix is an appropriate tool for systematic evaluation and elimination, and it is also beneficial for documentation of the decision-making process since the matrix is self-documenting. Further, the matrix provides a good overview of a great amount of information, which can be used as visual means to support communication of project status.

The methodology presents a concept comparison matrix that originates from a concept selection matrix that has been used internally at Husqvarna Construction Products but has been modified following principles from established decision matrices, such as the Elimination matrix and the Pugh matrix. The concept comparison matrix takes both requirements and wishes into consideration, and is used to eliminate concepts based on criteria fulfillment and based on comparison.

Comprising the requirements in the evaluation criteria provides an effective way to eliminate unfeasible concepts that are not fulfilling what is required of the product. The wishes support derivation of pros and cons for each concept, and also comparison of concepts, similar to a Pugh matrix. However, Pugh provides methods for relative comparison using a reference datum, which is not comprised in the comparison matrix. Evaluation against the different criteria also serves the purpose of identifying knowledge gaps to bridge. Information and knowledge of the concepts are crucial to make adequate decisions of elimination and comparisons between the different concepts. Further, the evaluation also provides support for the identification of relevant modifications or enhancements of concepts.

5.2.3 Concept Development Toolbox

The Concept Development Toolbox presents the proposed methodology, described in section *5.2.2 Proposition of methodology.* The Toolbox consists of two parts, a Handbook and a Template. The Handbook aims to describe the methodology, the purpose of each phase, and how to execute the activities in each phase. The Template aims to support the execution, facilitate documentation and provide templates for each presented method and tool suggested in the Handbook. In *Figure 5.2* the Toolbox structure can be seen.

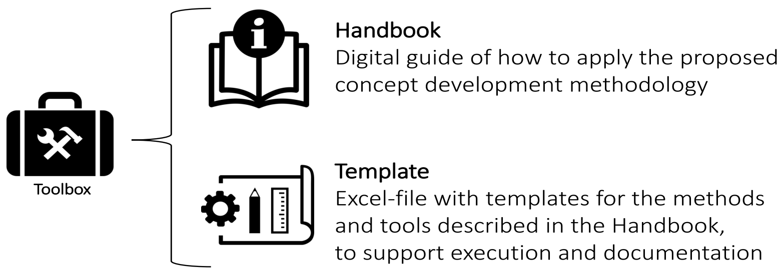

Figure 5.2: The Toolbox consists of a Handbook and a Template

The Toolbox has been divided into two parts for different reasons. One reason being that the information included in the Toolbox is extensive and to present it in one place was considered inappropriate, due to users perceiving it as too complex and comprehensive to take in. Another reason is that the information also addresses different aspects, one being the theoretical aspect and another is the practical aspect. Hence, it was decided suitable to divide the information and present it into two parts. It should be emphasized that the Handbook and the Template complement each other. In a concept development project, they should be used simultaneously to ensure that the methodology is applied correctly. However, when the methodology has been used in several concept development projects and there is enough knowledge and experience, only the Template can be used.

To make the Toolbox user-friendly, both Handbook and Template follow a structure based on the four phases of the methodology. Each phase is assigned a different color, which is used to color-code the different sections related to each phase. The color codes and names of the sections and activities are the same in both the Handbook and Template.

The Handbook and Template are presented in the file formats Microsoft PowerPoint and Microsoft Excel, respectively. These are established file formats used at Husqvarna Construction Products. Presenting the Toolbox in digital format facilitates accessibility for users since it can be stored and shared easily through SharePoint and/or email. Digital format in combination with established file formats also facilitates and enables the users at Husqvarna Construction Products to change, add, and/or update the Toolbox themselves.

5.2.3.1 Handbook

The Handbook is a digital guide that aims to give the user an understanding of the methodology regardless of the user's previous knowledge and experience of design methodologies. The Handbook describes the purpose and importance of each phase in the methodology, instructions for execution of each phase, how the suggested methods and tools within each phase should be used, and what the expected outcome is. The complete Handbook can be seen in *Appendix A*.

Handbook structure

The Handbook is divided into different segments and chapters. It begins with a presentation of general information of the Handbook, the usage and application, and the core of the methodology, to provide the prerequisites essential for the appropriate usage of the Handbook. The chapters are presenting the phases of the proposed methodology, where each phase is assigned a chapter. Each chapter follows the same structure of presenting theoretical information about the phase and also explanations of how to execute the methods and tools proposed in each phase, see *Figure 5.3*. References and appendix can be found at the end of the Handbook.

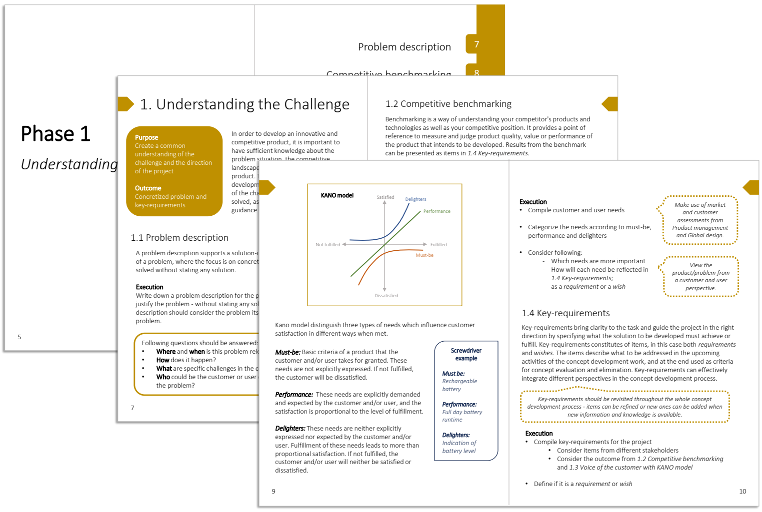

Figure 5.3: The structure of the the chapters in the Handbook

Selection of content

From the findings from the interviews and the creation process, it was found that the Handbook should not comprise too extensive content to support the reading and grasp of it. Hence, the content should be balanced and comprise the least amount of information necessary to support understanding of the methodology and why and how to execute each phase. Thus, the content mainly focuses on descriptions of the purpose, benefits, execution, and expected outcome, of each phase and associated methods and tools, see *Figure 5.4*. Descriptions of other aspects, such as theoretical backgrounds and challenges, may provide a more thorough understanding, but it was not included due to limitations of content.

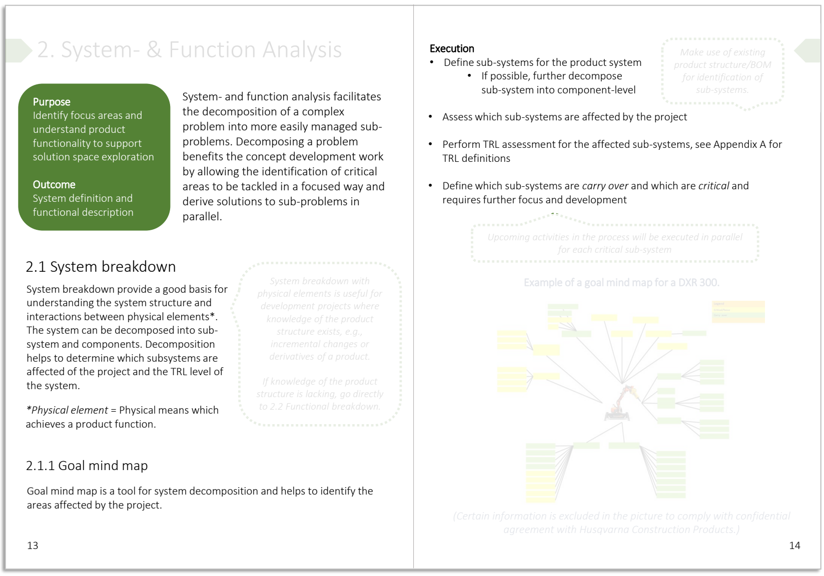

Figure 5.4: Chapter 2 in the Handbook with the two main types of content highlighted: purpose, expected outcome and benefits to the left, and the execution of the methods and tools to the right

Figures and examples

During the feedback loops, it emerged that several methods in the Handbook needed to be exemplified to facilitate understanding. Throughout the Handbook, figures and examples appear, to explain and clarify parts of the content. Some examples demonstrate the result of the method, e.g. *Figure 5.5* exemplifying a decomposed system with a Goal mind map. Other examples illustrates how to use the method or tool, e.g. *Figure 5.6* demonstrating how to combine sub-solutions to total solutions with a Concept combination matrix.

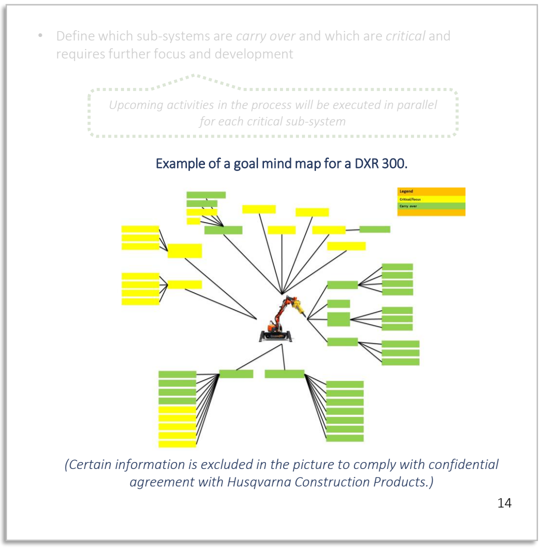

Figure 5.5: An example of the tool goal mind map presented in the Handbook

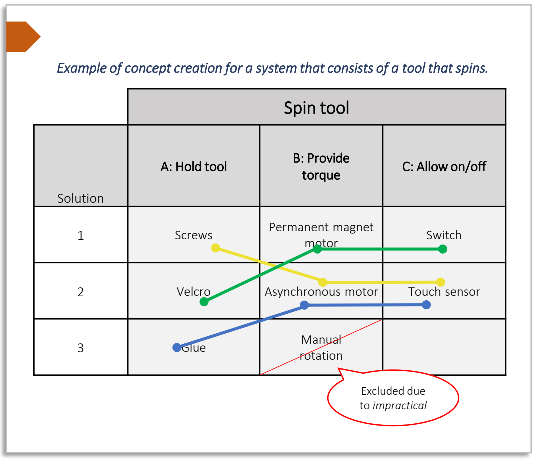

Figure 5.6: An example of the tool combination matrix presented in the Handbook

It was mentioned that the examples used in the previous efforts to introduce set-based concurrent engineering did not bring clarity of understanding of the methods. Hence it was important to create the examples for the Handbook together with candidates during the creation process, to ensure that the examples bring value to them. The examples are showing the basic principles of the methods and are simplified versions, thus not as extensive as the methods would be if applied in a real project. One example illustrates a functional tree for a sub-system with the main function *spin tool*, decomposed into three sub-functions. Several products at Husqvarna Construction Products comprise the function of spinning a tool, hence this simplified example was proposed by a candidate to be an appropriate example since many people can relate to it. The example for concept combination matrix derives from the same decomposed sub-functions, see *Figure 5.6*. In this example, classes of different kinds of solutions are used for the sub-functions, to illustrate how the matrix and sub-functions facilitate broad exploration of solutions, which is something rarely done currently at Husqvarna Construction Products.

Hints

In each phase, hints appear that should catch the reader's attention. The hints aim to provide tips and tricks that can support the execution. Each hint is presented in the same way, in a box with a dashed line colored in accordance with the phase. The hints can either provide tips and tricks to ease the execution of a specific activity or make the user aware of something specifically important, as seen in *Figure 5.7*.

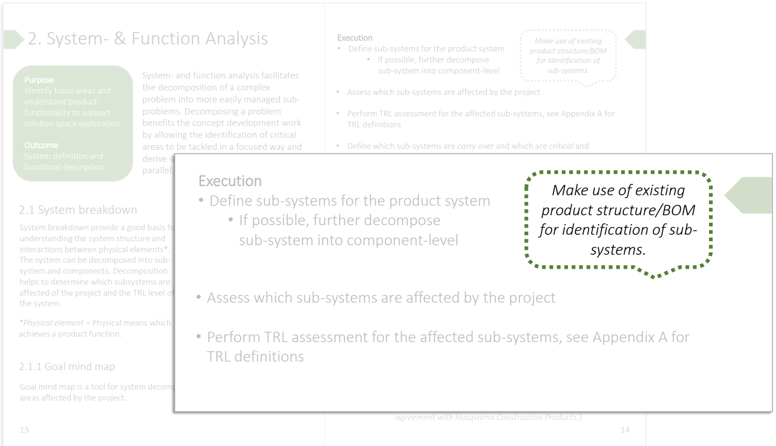

Figure 5.7: Example of a hint used in the Handbook

5.2.3.2 Template

The template is a Microsoft Excel file with predefined templates for the methods and tools presented in the Handbook. This will support the practical execution and usage of each method and tool, as well as facilitate documentation. In addition, each template can be used as a visual means to communicate the status and results of the concept development project during meetings. The documentation is done digitally directly in the Excel file and is advantageous because the amount of documentation will differ between projects and the required space can be adapted. The complete Template can be seen in *Appendix B*.

Template structure

The template consists of several excel sheets, *Figure 5.8* illustrates the different sheets in the bottom of the figure. The first sheet provides general information of the Toolbox, the usage, and application, and the core of the methodology, to provide the prerequisites essential for the appropriate usage of the Template. It also used to write down and specify information about the project that the template is used. Further, the following sheets are presented in accordance with the phases of the methodology. Specific templates for each of the methods and tools presented in the Handbook are provided in the sheets. In each sheet, references to associated pages in the Handbook are given.

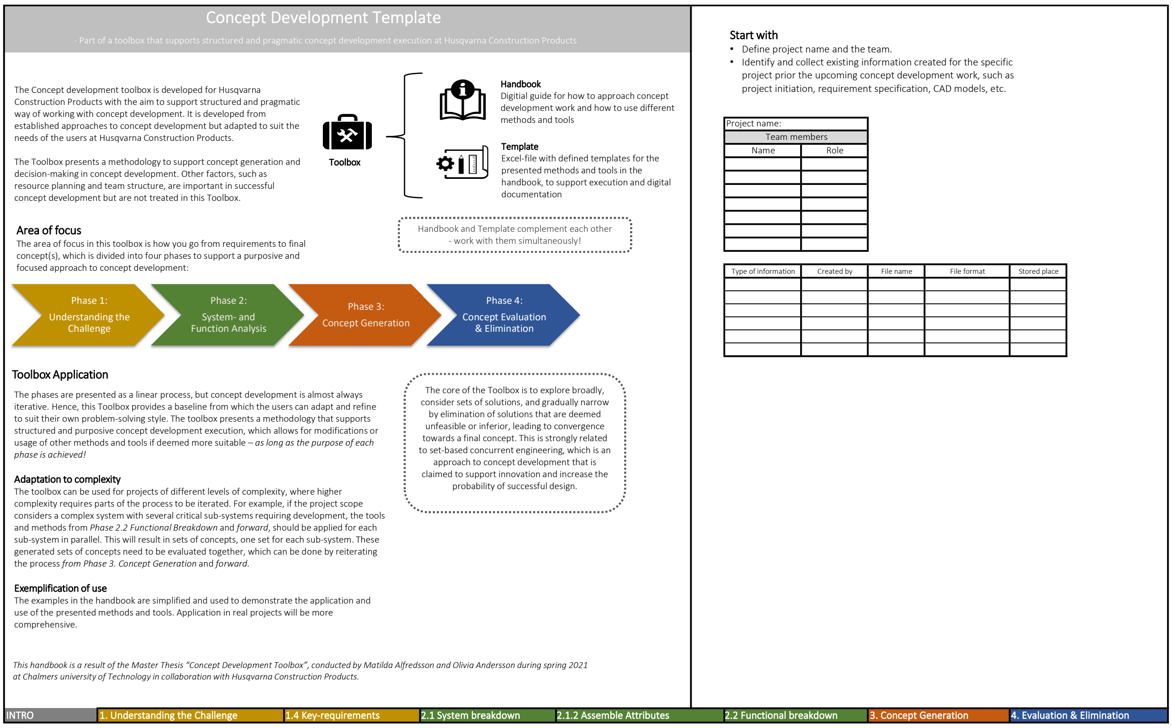

Figure 5.8: Visualization of the first sheet of the Template, also visualizing access to the other sheets at the bottom of the figure

Selection of content

The Template aims to facilitate the practical application of the proposed methodology, thus the selected content is focused on describing the execution of the various methods and tools in each phase and providing templates for each one. In opposite to the Handbook, the Template does not provide extensive information about each phase, but the purpose and outcome of each phase are presented along with the description of execution and the templates. In *Figure 5.9*, one sheet from the Template can be seen.

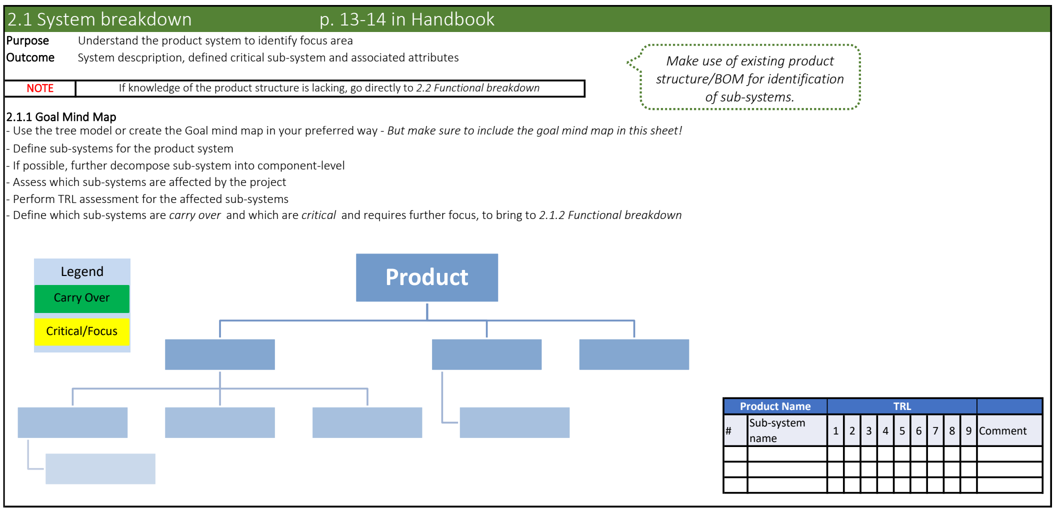

Figure 5.9: One of the sheets presented in the Template

Templates for tools and methods

The templates provided for each of the presented methods and tools mainly constitute tables, matrices, and forms, see *Figure 5.10* for a combination matrix and *Figure 5.11* for a functional tree. These templates are all easy to adjust and modify to suit the needs of the project and user. Having it in Microsoft Excel allows for easy changes, such as adding, removing, reshaping, or resizing different parts of the templates.

	Main function														
Solution	Sub-function A	Attribute 1	Attribute 2	Attribute 3	Organizational readiness	Sub-function B	Attribute 1	Attribute 2	Attribute 3	Organizational readiness	Sub-function C	Attribute 1	Attribute 2	Attribute 3	Organizational readiness
1	Sub-solution A1					Sub-solution B1					Sub-solution C1				
2	Sub-solution A2					Sub-solution B2					Sub-solution C2				
3	Sub-solution A3					Sub-solution B3									
4															

Figure 5.10: A template for the combination matrix presented in the Template

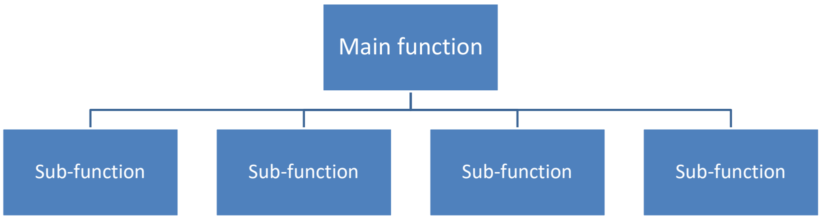

Figure 5.11: A template for the functional tree presented in the Template

5.3 Summary of Results

Chapter 5 presents the different results from this project; the empirical findings of the current situation at Husqvarna Construction Products in terms of concept development, and the result of the Concept Development Toolbox developed for Husqvarna Construction Products. The empirical findings define the current way that concept development is executed at Husqvarna Construction Products and the challenges related to it, with the purpose to highlight aspects for consideration in the development of the Concept Development Toolbox.

The Concept Development Toolbox is the main result of this project based on the project purpose. It is a Toolbox that aims to facilitate structured and pragmatic concept development execution at Husqvarna Construction Products. It presents a proposed methodology divided into four different phases, to support focused and purposive execution, and prescribes activities of how to go from requirements to a solution. It is developed from theoretically established concept development methodologies adapted according to the empirical findings and the input from the candidates during the creation process. The proposed methodology is influenced by set-based approaches to concept development to support the exploration and consideration of several alternative solutions according to the project scope.

The final result is a Toolbox of two parts with distinguished purposes, a Handbook, and a Template. The Handbook aims to facilitate understanding of the methodology and descriptions for the execution of the presented activities. The Template aims to support the practical application of the methodology by providing templates for each of the presented methods and tools in the Handbook. Together, the two parts form the Concept Development Toolbox that has been developed in collaboration with candidates from Husqvarna Construction Product, to facilitate implementation and usage at Husqvarna Construction Products.

6 Discussion

This chapter will reflect and discuss the following instances found upon completion of the project; Project task, Adaptation of theoretical methodologies for an industrial setting, Concept development at Husqvarna Construction Products, Concept Development Toolbox creation process, Usefulness and shortcomings of the Concept Development Toolbox as well as Improvement potential for concept development.

6.1 Project task

The project made it evident that the project task, of developing a Concept Development Toolbox that aims to support structured and pragmatic concept development execution, is of relevance. From the empirical findings, it showed that the current way of working does not comprise structured methodical concept development, different approaches are undertaken and commonly a point-based approach is used. A point-based approach is described in the literature as an approach that does not support the exploration and consideration of several alternatives, which was highlighted as an initial request for the Toolbox developed in this project. Further, the literature presents the set-based approach to concept development as more suitable in terms of improving time-to-market in product development projects since it prevents problems in later stages in the development process, which further justifies the project task of proposing a methodology that facilitates consideration of several alternatives.

The findings also highlighted that there are different levels of knowledge and experience of concept development design methodologies, which currently make it difficult to introduce methods and tools to support the execution. This project presents a Concept Development Toolbox that serves as a common approach for concept development, presented in a format that supports the usage without previous knowledge and experience.

Different attitudes towards the purpose and necessity of this project task were found at Husqvarna Construction Products throughout the project. The project is initiated from higher organizational levels, and not from the intended users of the Toolbox. The users that were interviewed in this project were not all positive to the Toolbox, mainly because Husqvarna Construction Products currently and historically develops successful products, thus the need to change the way concept development is executed may not be apparent. This clearly demonstrates one of the main challenges of this project: creating a Concept Development Toolbox that also appeals to the individuals not fond of the idea of using it.

6.2 Adaptation of theoretical methodologies for an industrial setting

Design methodologies for concept development are in theory commonly described for an ideal use case. The descriptions rarely consider the challenges that exist in industrial settings that affect practical applicability. The challenges at Husqvarna Construction Products mainly concern pressured time plans and different levels of knowledge and experience of design methodologies. This project has comprised proposing a methodology for purposive concept development, that is not complex, comprehensive, or demanding. Hence, the methods presented in theory have had to be adapted by simplifications, removal of execution steps, and merging of different methods. Thus, one of the challenges in this project has been to find a balance where adaptation of theoretical methodologies has not been carried out to the extent that the purpose of the methods is missed.

Several different alternative methods and tools can be used for the same purpose and the choices in the proposed methodology are mainly based on analysis and synthesis of theoretical findings and the findings at Husqvarna Construction Products. However, the researcher's knowledge and experiences of concept development design methodologies from academia, through studies in mechanical engineering and product development, were also considered for the decision of methods and tools to include in the proposed methodology. This may lead to biased choices, but practical experience and knowledge were deemed valuable for the work of adapting the theoretical methodologies for industrial settings.

6.3 Concept development at Husqvarna Construction Products

Interviews were conducted to understand how concept development is executed in practice at Husqvarna Construction Products. To further understand, the documents available in the Product Creation Process have been used. Observations of concept development execution in practice in a real project were not conducted in this project. Observations could have provided additional relevant aspects to the practical application, and perhaps the content and design of the Concept Development Toolbox would have been different. Relying on explanations of how concept development is executed may imply a risk of relevant aspects not being mentioned, such as aspects that the interviewee is either not aware of or does not recollect.

6.4 Concept Development Toolbox creation process

The creation process for the Toolbox involved candidates from Husqvarna Construction Products, as an endeavor to reach user acceptance. This provided them the opportunity of voicing their opinions and sharing feedback, as the basis for refinements and changes in the Toolbox. However, it was performed on a small scale considering the involvement of seven participants. How well the inputs from the candidates reflect the opinions of the larger scale has not been examined.

Participation in the creation process was voluntary. Several candidates were asked, but many rejected the invitation. The candidates that participated considered the Toolbox as helpful support and had a positive attitude towards working according to a structured methodology for concept development. Involving candidates that were not as willingly installed to the Toolbox could have provided other perspectives to consider in the creation process. Hence, the created Toolbox might not appeal to the different crowds of users at Husqvarna Construction Products.

6.5 Usefulness and shortcomings of the Concept Development Toolbox

The Toolbox is created to support the practical application of the concept development methodology, to facilitate structured and pragmatic concept development execution. The possibilities to test and evaluate the practical applicability together with the candidates were limited, due to delimitations of time and availability. Thus, the user assessment did not comprise the practice of applying the methods, but only comprised reflection and consideration to the aspect of practical applicability during the assessment of the proposed Toolbox.

The Toolbox is presented in a digital format and is designed for digital use. Both the handbook and the template can be printed into physical form, but they are not designed for that intent. Hence, the Toolbox may not appeal to someone who prefers to work with physical tools. To create the toolbox in a physical format was not found as a need during the interviews nor requested by any of the candidates, though it was brought to our attention during the creation process. However, the Toolbox is presented in file formats that are easy to adjust and modify to suit as a physical tool as well.

The Toolbox consists of two independent parts, but they are suggested to be used simultaneously to ensure that the methodology is applied correctly. However, consisting of two parts induce the risk of usage of only one part, assuming the template since it supports the practical application. This risk was considered during the creation process but presenting all the information and templates together in one place was considered worse. Presenting all information and content in one place would affect the possibility of using the Toolbox as a visual means to support communication of project status. Further, it was found that users at Husqvarna Construction Products are resilient to read and make use of tools if the content is too extensive.

6.6 Improvement potential for concept development at Husqvarna Construction Products

The project aims to improve the early product development project phases where the conceptual design is performed, by addressing the issue of not working structurally and purposive with concept development execution. Thus, this project mainly focuses on the methodology aspect, but other factors and aspects are essential for improving concept development. The empirical findings highlight other aspects not addressed in the Toolbox that Husqvarna Construction Products can incorporate in the endeavor of improving concept development. The aspects concerns project types, the collaboration between segments, and the development of robust solutions, that should be considered before initiating the concept development process. Further, the documentation aspect must be considered, in terms of storage and accessibility. Otherwise, it may be difficult to sustain the benefits of documentation, and the reluctance towards documenting may persist.

7 Conclusions & Recommendations

This report summarized the work done in a master thesis project for the company Husqvarna Construction Products. The following chapter will present the conclusions drawn during the project and recommendations for further work.

7.1 Conclusions

The purpose of this project was to develop a Toolbox aimed to support structured and pragmatic concept development execution at Husqvarna Construction Products. Husqvarna Construction Products are continuously striving to improve time-to-market for their product development projects, and the result of this project is a part of that endeavor. The Toolbox presents a methodology derived from theoretically established concept development methodologies further adapted to the situation at Husqvarna Construction Products to facilitate implementation and usage.

Initially, the project comprised research of the state of the art of concept development approaches, processes, methods, and tools through literature studies. The synthesis of relevant literature revealed deficiencies in descriptions of the practical applications of concept development methods in industrial settings. Thus, the methodology presented in the Toolbox is mainly based on concept development methodologies as described in academia.

The identification of the current status at Husqvarna Construction in terms of concept development justified the need for improving concept development and provided findings of different aspects to be addressed for that purpose. However, the project scope comprises the aspects directly related to concept development execution and methodologies, thus not for all the findings compiled in section *5.1.* Aspects related to team structure, collaboration between different organizational segments, and storage of documentation were not addressed in the development of the Toolbox.

A critical part of this project was the creation process of the Toolbox. This process was essential for reaching user acceptance, one of the objectives for this project, and creating something that would be of use for the development teams at Husqvarna Construction Products. The creation process of the Toolbox elicited new findings in addition to the findings addressed from the preceding interviews. User assessments and feedback loops provided necessary findings that heavily affected the decisions for the proposed methodology and the design of the Toolbox, thus had a large impact on the final result.

The practical applicability of the Toolbox was only evaluated through user assessments, by reflection and considerations of that aspect. To fully understand and make fair judgments of the Toolbox's applicability and how it supports pragmatic concept development execution, it must be applied in Husqvarna Construction Products specific development projects.

The Concept Development Toolbox is derived from theories claimed to support the objectives of long-term effects of improving innovation and time-to-market to maintain competitiveness. Those objectives have not been possible to evaluate in this project. To be able to evaluate whether the Toolbox contributes to these objectives, it is required to implement and use the Toolbox in one or several concept development projects.

Concluding, this project provides a Toolbox developed to support and facilitate structured and pragmatic concept development execution for Husqvarna Construction Products. It is developed from currently available theoretical concept development methodologies and adapted to suit the current situation at Husqvarna Construction Products. Hence, the Toolbox as presented now, may not comply with future needs or new methodologies. The Toolbox provides a baseline for continuous adaptations and improvement based on new needs and insights. The result presented now should be considered as a starting point in the endeavor of improving concept development execution at Husqvarna Construction Products.

7.2 Further work

This project provides a starting point for improving the early phases in product development projects, where the conceptual design is performed. The following recommendations are given to obtain the benefits that the Concept Development Toolbox can entail:

- A prerequisite for obtaining the benefits entailed from the Toolbox is to implement it in the current concept development processes at Husqvarna Construction Products. It is recommended to implement the Toolbox in the Product Creation Process, making it accessible for everyone at Husqvarna Construction Products.

- User acceptance is crucial for the usage of the Toolbox and this project comprised activities to reach user acceptance on a small scale. To reach user acceptance on a larger scale, it is recommended to provide opportunities for discussions and practice of using the Toolbox. Seminars and workshops are suggested for this purpose.

- The practical applicability was only evaluated to a certain degree, without practical testing. It is recommended to pilot the Toolbox in a project to further evaluate practical applicability and identify improvement potentials for that aspect.

Since this project is a starting point for improving the early phases of product development projects, it is recommended to continuously develop and change the concept development toolbox to ensure that it is adapted to the current situation of concept development and provides the best possible support for Husqvarna Construction Products.

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A Concept Development Toolbox - Handbook

Concept Development Handbook

- Part of a Toolbox that supports structured and pragmatic concept development execution at Husqvarna Construction Products

This handbook is a result of the Master Thesis "Concept Development Toolbox", conducted by Matilda Alfredsson and Olivia Andersson during spring 2021 at Chalmers university of Technology in collaboration with Husqvarna Construction Products.

Concept Development Toolbox

The Concept development toolbox is developed for Husqvarna Construction Products with the aim to support structured and pragmatic way of working with concept development. It is developed from established approaches to concept development but adapted to suit the needs of the users at Husqvarna Construction Products.

The Toolbox presents a methodology to support concept generation and decision-making in concept development. Other factors, such as resource planning and team structure, are important in successful concept development but are not treated in this Toolbox.

Toolbox Structure

Toolbox

- **Handbook**
  Digital guide of how to apply the proposed concept development methodology
- **Template**
  Excel-file with templates for the methods and tools described in the handbook, to support execution and documentation

Handbook and Template complement each other - work with them simultaneously!

Area of focus

The area of focus in this toolbox is how you go from requirements to final concept(s), which is divided into four phases to support a purposive and focused approach to concept development:

- **Understanding the Challenge:** *Create a common understanding of the challenge and the direction of the project*
- **System- & Function Analysis:** *Identify focus areas and understand product functionality to support solution space exploration*
- **Concept Generation:** *Explore the solution space by generating sets of concepts*
- **Concept Evaluation & Elimination:** *Systematically evaluate and eliminate concepts based on knowledge to converge on final concept(s)*

The core of the Toolbox is to explore broadly, consider sets of solutions, and gradually narrow by elimination of solutions that are deemed unfeasible or inferior, leading to convergence towards a final concept. This is strongly related to set-based concurrent engineering, which is an approach to concept development that is claimed to support innovation, improve time-to-market, and increase the probability of successful design.

Toolbox application

The phases are presented as a linear process, but concept development is almost always iterative. Hence, this Toolbox provides a baseline from which the users can adapt and refine to suit their own problem-solving style. The toolbox presents a methodology that supports structured and purposive concept development execution, which allows for modifications or usage of other methods and tools if deemed more suitable – *as long as the purpose of each phase is achieved!*

Adaptation to complexity

The toolbox can be used for projects of different levels of complexity, where higher complexity requires parts of the process to be iterated. For example, if the project scope considers a complex system with several critical sub-systems requiring development, the tools and methods from *Phase 2.2 Functional Breakdown* and *forward*, should be applied for each sub-system in parallel. This will result in sets of concepts, one set for each sub-system. These generated sets of concepts need to be evaluated together, which can be done by reiterating the process *from Phase 3. Concept Generation* and *forward.*

Exemplification of use

The examples in the handbook are simplified and used to demonstrate the application and use of the presented methods and tools. Application in real projects will be more comprehensive.

Table of content

Phase 1

Understanding the Challenge

1. Understanding the Challenge

Purpose
Create a common understanding of the challenge and the direction of the project

Outcome
Concretized problem and key-requirements

In order to develop an innovative and competitive product, it is important to have sufficient knowledge about the problem situation, the competitive landscape, and targets for the intended product. This phase in concept development provides a common view of the challenge, the problem to be solved, associated focus areas, and guidance for upcoming activities.

1.1 Problem description

A problem description supports a solution-independent exploration of a problem, where the focus is on concretizing the problem to be solved without stating any solution.

Execution
Write down a problem description for the project. Describe and justify the problem - without stating any solution. The problem description should consider the problem itself and the context of the problem.

Following questions should be answered:
- **Where** and **when** is this problem relevant?
- **How** does it happen?
- **What** are specific challenges in the context of the problem?
- **Who** could be the customer or user of a solution for the problem?

1.2 Competitive benchmarking

Benchmarking is a way of understanding your competitor's products and technologies as well as your competitive position. It provides a point of reference to measure and judge product quality, value or performance of the product that intends to be developed. Results from the benchmark can be presented as items in *1.4 Key-requirements.*

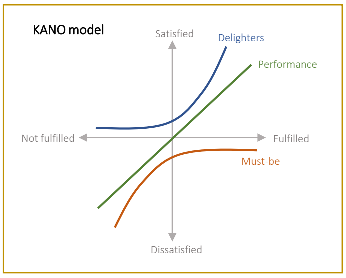
Execution
- Identify relevant design issues and properties
- Identify competing or related products, both internally and externally
- Conduct the information search
- Systemize the information
- Analyze best in class per property, industry trends and opportunities for obtaining unique selling points

1.3 Voice of the customer with KANO model

It is crucial to focus on customer and user needs in order to develop competitive products, and the focus should prevail throughout the entire development project.

Considerations to the customer and user needs must be taken before the product design has been decided, to avoid late, costly and time-consuming product changes. Thus, the customer and user needs have a vital role in concept development and the needs should be reflected in the *1.4 Key requirements*.

The Kano model is a method to help understand different types of customer and user needs, that need to be addressed from a competitive perspective.



Kano model distinguish three types of needs which influence customer satisfaction in different ways when met.

Must-be: Basic criteria of a product that the customer and/or user takes for granted. These needs are not explicitly expressed. If not fulfilled, the customer will be dissatisfied.

Performance: These needs are explicitly demanded and expected by the customer and/or user, and the satisfaction is proportional to the level of fulfillment.

Delighters: These needs are neither explicitly expressed nor expected by the customer and/or user. Fulfillment of these needs leads to more than proportional satisfaction. If not fulfilled, the customer and/or user will neither be satisfied or dissatisfied.

Screwdriver example

Must be: *Rechargeable battery*

Performance: *Full day battery runtime*

Delighters: *Indication of battery level*

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Execution
- Compile customer and user needs
- Categorize the needs according to must-be, performance and delighters
- Consider following:
  - Which needs are more important
  - How will each need be reflected in *1.4 Key-requirements;* as a *requirement* or a *wish*

Make use of market and customer assessments from Product management and Global design.

View the product/problem from a customer and user perspective.

1.4 Key-requirements

Key-requirements bring clarity to the task and guide the project in the right direction by specifying what the solution to be developed must achieve or fulfill. Key-requirements constitutes of items, in this case both *requirements* and *wishes*. The items describe what to be addressed in the upcoming activities of the concept development work, and at the end used as criteria for concept evaluation and elimination. Key-requirements can effectively integrate different perspectives in the concept development process.

Key-requirements should be revisited throughout the whole concept development process - items can be refined or new ones can be added when new information and knowledge is available.

Execution
- Compile key-requirements for the project
  - Consider items from different stakeholders
  - Consider the outcome from *1.2 Competitive benchmarking* and *1.3 Voice of the customer with KANO model*
- Define if it is a *requirement* or *wish*

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Phase 2

System- & Function Analysis

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2. System- & Function Analysis

Purpose
Identify focus areas and understand product functionality to support solution space exploration

Outcome
System definition and functional description

System- and function analysis facilitates the decomposition of a complex problem into more easily managed sub-problems. Decomposing a problem benefits the concept development work by allowing the identification of critical areas to be tackled in a focused way and derive solutions to sub-problems in parallel.

2.1 System breakdown

System breakdown provide a good basis for understanding the system structure and interactions between physical elements*. The system can be decomposed into sub-system and components. Decomposition helps to determine which subsystems are affected of the project and the TRL level of the system.

**Physical element* = Physical means which achieves a product function.

System breakdown with physical elements is useful for development projects where knowledge of the product structure exists, e.g., incremental changes or derivatives of a product.

If knowledge of the product structure is lacking, go directly to 2.2 Functional breakdown.

2.1.1 Goal mind map

Goal mind map is a tool for system decomposition and helps to identify the areas affected by the project.

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Execution

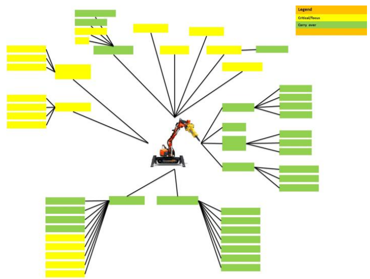
- Define sub-systems for the product system
  - If possible, further decompose sub-system into component-level

Make use of existing product structure/BOM for identification of sub-systems.

- Assess which sub-systems are affected by the project
- Perform TRL assessment for the affected sub-systems, see Appendix A for TRL definitions
- Define which sub-systems are *carry over* and which are *critical* and requires further focus and development

Upcoming activities in the process will be executed in parallel for each critical sub-system

Example of a goal mind map for a DXR 300.



(Certain information is excluded in the picture to comply with confidential agreement with Husqvarna Construction Products.)

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2.1.2 Assemble attributes

It is necessary to define attributes for each critical sub-system to identify the allowed solution space. Knowing the solution space provide guidance for generation of feasible solutions. While key-requirements address the total solution, the attributes address what needs to be achieved by each critical sub-system.

Execution

- Compile attributes for each critical sub-system
  - Attributes can be found through items in *1.4 Key-requirements* and other relevant aspects, e.g., adjacent sub-systems can affect the available space for the sub-system.

Make use of the Goal mind map to support identification of other aspects to consider in attributes.

Example *RPM is a relevant attribute for a sub-system that provides torque, and the feeling of grip is a relevant attribute for a sub-system that consists of a handle.*

2.2 Functional breakdown

Functional breakdown provides a good basis for understanding the intended behavior of the system and important aspects to consider when generating solutions. This is done by decomposing the system into functional elements*.

**Functional element* = Intended behavior of the product. The function should be expressed as *verb + noun* and may contain contextual information.

Functional elements supports exploration of more innovative alternative solutions in Phase 3 Concept Generation.

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2.2.1 Functional tree

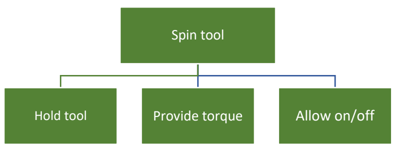
Functional tree is a tool to help visualize the functional decomposition of the system.

Execution

- If *2.1 System breakdown* was executed, define the main functional element of the critical sub-system, else define the main functional element for the solution to be developed
- Decompose the main functional element into sub-functional elements

Create a Functional tree for each critical sub-system

Example of a functional tree for a system that consists of a tool that spins.



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Phase 3

Concept Generation

3. Concept Generation

Purpose
Explore the solution space by generating sets of concepts

Outcome
Several alternative concepts, minimum of three

Generating several alternative concepts will support a broader exploration of the solution space and increase the possibility to find the most appropriate solution to the given problem. A concept consist of several sub-solutions that are combined into a total solution.

3.1 Sub-solution generation

Generating sub-solutions to sub-problems is a method to solve a problem in a focused way. The sub-problems are here presented as functional elements. The aim is to freely generate several alternative sub-solutions to each sub-function and assess each sub-solution against attributes, as well as the organizational readiness.

The assessment provides support for the identification of clearly inferior alternatives, as well as alternatives outside the allowed solution space.

Execution

- Make use of a combination matrix and insert the functional elements from *2.2 Functional breakdown*

Use a combination matrix for each critical sub-system.

- Generate several alternative sub-solutions to the decomposed elements. This can be supported by following activities:
  - Brainstorming
  - Analogies with technical systems in other domains
  - Analysis of competitors' products and internal existing products
  - Search in literature
  - Interviews with experts and/or lead users
- If applicable, assign attributes to each sub-function and perform a preliminary assessment of each sub-solution , make us of:
  - *2.1.2 Assemble attributes* if executed, else
  - derive attributes from *1.4 Key-requirements*
- If applicable, assess the organizational readiness for each sub-solution; *Previous experiences, knowledge, production capabilities, etc.*

An example of how to use the matrix is illustrated on the next page.

Example of sub-solution generation for a system that consists of a tool that spins.

	Spin tool		
Solution	A: Hold Tool	B: Provide torque	C: Allow on/off
1	Screws	Permanent magnet motor	Switch
2	Velcro	Asynchronous motor	Touch sensor
3	Glue	Manual rotation	

Sub-solution generation can be done to different levels of detail and is an iterative process. The example above illustrate a sub-solution generation on a lower level of detail. The sub-solutions in the matrix are presented as classes or categories of sub-solutions, which allows for a broad exploration of solution space. The process can be iterated by looking into detailed and specific sub-solutions within each category, which enables easier assessment against attributes.

3.2 Concept creation

Concepts are created by systematically combining sub-solutions into total solutions in a Combination matrix. This method is used to generate as many conceivable concepts as possible, to create a set of concepts.

It is important to generate several alternative concepts, it does not have to be the "best" combination or a combination that is likely to be the final – *what you think is the "best" or final combination might not be true!*

Execution

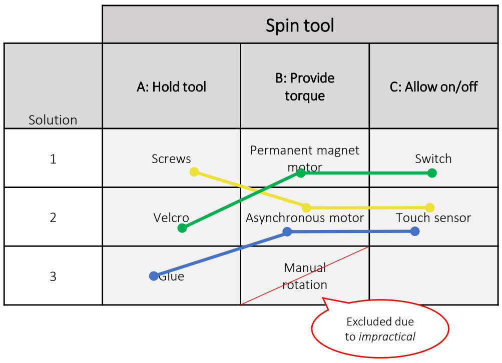
- Create concepts by combining sub-solutions, using colored lines for each concept
- Give names to each concept and present the set of concepts in a list
- If any additional methods have been used for concept generation, include the results from that in the list as well

Exclude combinations of clearly inferior or unfeasible sub-solutions and/or exclude combinations of different sub-solutions that are incompatible or clearly inferior.

Make sure to comment on reasons for exclusion!

It is important that the different combinations of sub-solutions represent distinct principles or classes of concepts.

Example of concept creation for a system that consists of a tool that spins.



The Combination matrix can be used to combine sets of concepts for different critical sub-systems in a product, resulting in a new set of concepts to further evaluate:

- *Sub-functions will in that case be the main functions of each critical sub-system*
- *Sub-solutions will be the concepts from each sets for the different sub-systems*

Phase 4

Concept Evaluation & Elimination

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Concept comparison matrix 27

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4. Concept Evaluation & Elimination

Purpose
Systematically evaluate and eliminate concepts based on knowledge to converge on final concept(s)

Outcome
Final concept(s)

Systematic evaluation is used to gradually eliminate weaker alternatives based on knowledge, instead of directly trying to select the "best" option. Decision matrices are suitable for systematic evaluation and are beneficial for evaluation of sets of concepts. It provides a good overview of great amount of information, supports documentation of decisions and effectively integrates different perspectives.

4.1 Concept comparison matrix

The purpose of Concept comparison matrix is to evaluate and compare a set of concepts against criteria, to support elimination and convergence to final concept(s). The Concept comparison matrix is beneficial for evaluating several concepts at once by providing an overview of information that supports identification of deficiencies and superior concepts. It is also working as a historical record for future reference of how concepts fulfill certain criteria.

Documentation of concept evaluation and elimination is significant for traceability as well as knowledge capture and reuse.

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Execution

- List the set of concepts in a Concept comparison matrix
- List relevant criteria and specify values for each concept.
  - Criteria should reflect:
    - Requirements from *1.4 Key-requirements*
    - Wishes from *1.4 Key-requirements*
    - Attributes and other relevant aspects;
      e.g., Level of risk, realizable, aligned with product portfolio
- Evaluate if the concept *fulfill the criteria*, *do not fulfill the criteria* or if *more knowledge is needed*
- Perform activities to close knowledge gaps

Knowledge can be created and captured through further development and analysis, from other functional areas, expert reviews, and through research.

- Eliminate concepts that do not fulfill *requirements*
- Analyze the information in the matrix and define pros and cons for each remaining concept
- Compare the concepts and if possible, decide on concept(s) to proceed with, consider following:
  - *Different criteria have different relative importance*
  - *Different stakeholders value criteria differently*
- Clearly mark the concept(s) to proceed with

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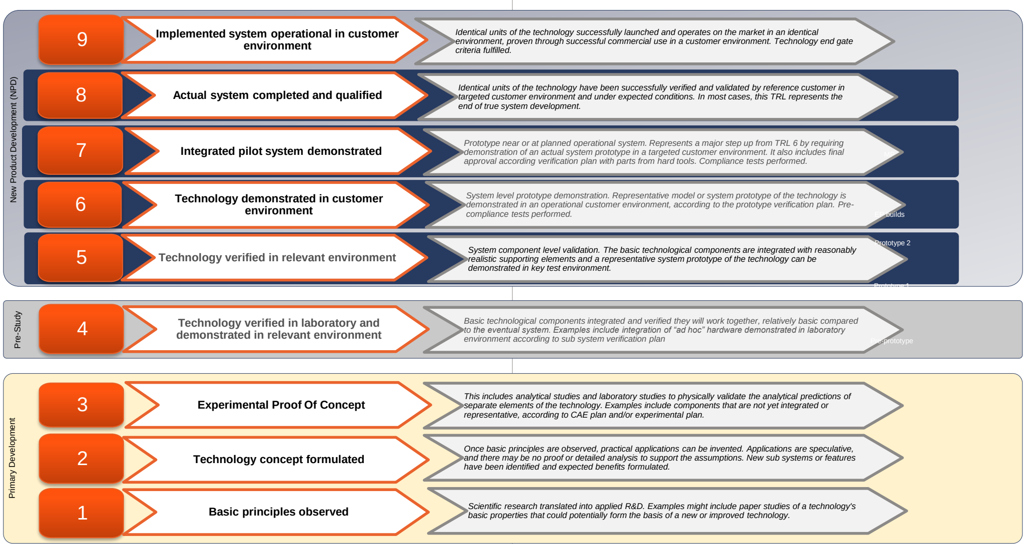
Appendix A: TRL definitions



B Concept Development Toolbox - Template

Concept Development Template

- Part of a toolbox that supports structured and pragmatic concept development execution at Husqvarna Construction Products

The Concept development toolbox is developed for Husqvarna Construction Products with the aim to support structured and pragmatic way of working with concept development. It is developed from established approaches to concept development but adapted to suit the needs of the users at Husqvarna Construction Products.

The Toolbox presents a methodology to support concept generation and decision-making in concept development. Other factors, such as resource planning and team structure, are important in successful concept development but are not treated in this Toolbox.

Toolbox

Handbook
Digitial guide for how to approach concept development work and how to use different methods and tools

Template
Excel-file with defined templates for the presented methods and tools in the handbook, to support execution and digital documentation

Handbook and Template complement each other - work with them simultaneously!

Area of focus

The area of focus in this toolbox is how you go from requirements to final concept(s), which is divided into four phases to support a purposive and focused approach to concept development:

Phase 1: Understanding the Challenge → Phase 2: System- and Function Analysis → Phase 3: Concept Generation → Phase 4: Concept Evaluation & Elimination

Toolbox Application

The phases are presented as a linear process, but concept development is almost always iterative. Hence, this Toolbox provides a baseline from which the users can adapt and refine to suit their own problem-solving style. The toolbox presents a methodology that supports structured and purposive concept development execution, which allows for modifications or usage of other methods and tools if deemed more suitable – *as long as the purpose of each phase is achieved!*

The core of the Toolbox is to explore broadly, consider sets of solutions, and gradually narrow by elimination of solutions that are deemed unfeasible or inferior, leading to convergence towards a final concept. This is strongly related to set-based concurrent engineering, which is an approach to concept development that is claimed to support innovation and increase the probability of successful design.

Adaptation to complexity
The toolbox can be used for projects of different levels of complexity, where higher complexity requires parts of the process to be iterated. For example, if the project scope considers a complex system with several critical sub-systems requiring development, the tools and methods from *Phase 2.2 Functional Breakdown* and *forward*, should be applied for each sub-system in parallel. This will result in sets of concepts, one set for each sub-system. These generated sets of concepts need to be evaluated together, which can be done by reiterating the process *from Phase 3. Concept Generation* and *forward.*

Exemplification of use
The examples in the handbook are simplified and used to demonstrate the application and use of the presented methods and tools. Application in real projects will be more comprehensive.

This handbook is a result of the Master Thesis "Concept Development Toolbox", conducted by Matilda Alfredsson and Olivia Andersson during spring 2021 at Chalmers university of Technology in collaboration with Husqvarna Construction Products.

Start with

- Define project name and the team.
- Identify and collect existing information created for the specific project prior the upcoming concept development work, such as project initiation, requirement specification, CAD models, etc.

Project name:	
Team members	
Name	Role

Type of information	Created by	File name	File format	Stored place

1. Understanding the Challenge

p. 5-10 in Handbook

Purpose Create a common understanding of the challenge and the direction of the project.
Outcome Concretized problem and key-requirements.

1.1 Problem description
- Describe and justify the problem - without stating any solution.

Problem description
Where *and* ***when*** *is this problem relevant?*
How *does it happen?*
What *are specific challenges in the context of the problem?*
Who *could be the customer or user of a solution for the problem?*

1.2 Competitive benchmarking
- Perform a benchmark to understand the competitive landscape
- How is the problem solved today? Identify relevant design issues and properties.
- Look into internal- and competitor' products and technologies.

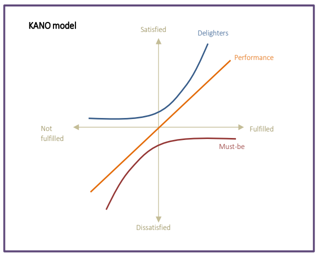
Properties/design issue	Products		
	Product name	Product name	Product name

1.3 Voice of the customer with KANO model
- Compile customer and user needs
- Categorize the needs according to *must-be*, *performance* and *delighters*
- Consider following:
  - Which needs are more important
  - How will each need be reflected in *1.4 Key-requirements* - as a *requirement* or a *wish*

Make use of market and customer assessments from Product management and Global design

View the product/problem from a customer and user perspective

Customer and user needs		
Need	Must-be/Performance/Delighter	Comments



Must-be: Basic criteria of a product that the customer and/or user takes for granted. These needs are not explicitly expressed. If not fulfilled, the customer will be dissatisfied.

Performance: These needs are explicitly demanded and expected by the customer and/or user, and the satisfaction is proportional to the level of fulfillment.

Delighters: These needs are neither explicitly expressed nor expected by the customer and/or user. Fulfillment of these needs leads to more than proportional satisfaction. If not fulfilled, the customer and/or user will neither be satisfied or dissatisfied.

1.4 Key-requirements

p. 10 in Handbook

- Compile key-requirements for the project, make sure that user needs are considered!
- Define, if possible, **target value** for the item
- Define if it is a **requirement** or **wish** [R/W]
- **Justify** the item
- Define **date** for establishment of item

Key-requirements

No.	Item	unit	Description	Target Value	R/W	Justification (why/who)	Comments	Date of Issue
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

2.1 System breakdown

p. 13-14 in Handbook

Purpose Understand the product system to identify focus area

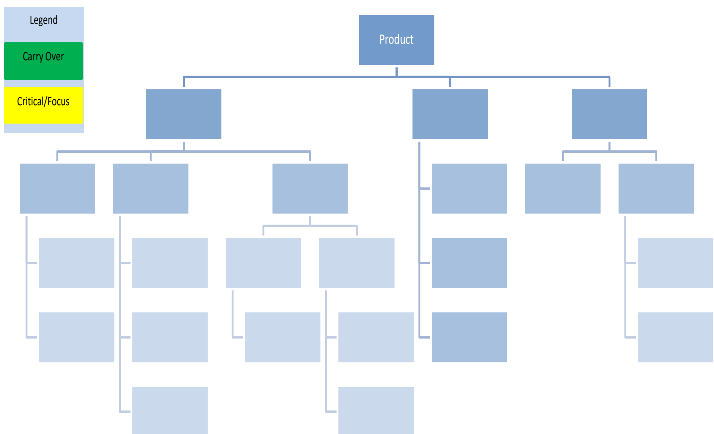
Outcome System descpription, defined critical sub-system and associated attributes

NOTE If knowledge of the product structure is lacking, go directly to *2.2 Functional breakdown*

Make use of existing product structure/BOM for identification of sub-systems

2.1.1 Goal Mind Map

- Use the tree model or create the Goal mind map in your preferred way - ***But make sure to include the goal mind map in this sheet!***
- Define sub-systems for the product system
- If possible, further decompose sub-system into component-level
- Assess which sub-systems are affected by the project
- Perform TRL assessment for the affected sub-systems
- Define which sub-systems are *carry over* and which are *critical* and requires further focus, to bring to *2.1.2 Functional breakdown*



Product Name		TRL									
#	Subsystem name	1	2	3	4	5	6	7	8	9	Comment

2.1.2 Assemble Attributes

p. 15 in Handbook

- Compile attributes for each critical sub-system
- Attributes can be found through:
  - items in *1.4 Key-requirements*
  - other relevant aspects, e.g., adjacent sub-systems can affect the available space for the sub-system.

While key-requirements address the total solution, the attributes address what needs to be achieved by each critical sub-system.

Critical sub-system	
Attribute	Comments

3. Concept Generation

p.17-24 in Handbook

Purpose Explore the solution space by generating sets of solutions
Outcome Several alternative concepts, minimum of three

3.1 Sub solution generation
- Transfer functional elements from *2.2 Functional breakdown* into the matrix below
- Generate several alternative sub-solutions to each sub-function.
- If applicable, assign attributes to each sub-function and perform a preliminary assessment of each sub-solution , make us of:
  - *2.1.2 Assemble attributes* if executed, else
  - derive attributes from *1.4 Key-requirements*
- Define organizational readiness for each sub-solution; *Previous experiences, knowledge, production capabilities, etc.*

3.2 Concept creation
- Make combinations of sub-solutions by using colored lines for each concept. Exclude combinations of clearly inferior sub-solutions.
- Give names to each concept and list them in this sheet
- If any additional methods have been used for concept generation, include the results from that in the list as well.

Use the assessment of each sub-solution to exclude combinations of clearly inferior or unfeasible sub-solutions and/or exclude combinations of different sub-solutions that are incompatible.

	Main function																											
Solution	Sub-function A	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Organizational readiness	Sub-function B	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Organizational readiness	Sub-function C	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Organizational readiness	Sub-function D	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Organizational readiness
1	Sub-solution A1							Sub-solution B1							Sub-solution C1							Sub-solution D1						
2	Sub-solution A2							Sub-solution B2							Sub-solution C2													
3	Sub-solution A3							Sub-solution B3																				
4																												
5																												
6																												

4. Concept Evaluation & Elimination

p.25-28 in Handbook

Purpose Systematically evaluate and eliminate concepts based on knowledge to converge on final concept(s)

Outcome Final concept(s)

- List the set of concepts in the Concept comparison matrix below
- List relevant criteria and specify values for each concept

  Criteria should reflect:
  - requirements from *1.4 Key-requirements*
  - wishes from *1.4 Key-requirements*
  - attributes or other relevant aspects; e.g., Level of risk, realizable, aligned with product portfolio.
- Evaluate if the concept *fulfill the criteria* , *do not fulfill the criter ia* or if *more knowledge is needed*
- Perform activities to close the knowledge gaps
- Eliminate concepts that do not fulfill *requirements*
- Analyze the information in the matrix and define pros and cons for each remaining concept
- Compare the concepts and if possible, decide on concept(s) to proceed with, consider following:
  - *different criteria have different relative importance*
  - *different stakeholder value criteria differently*
- Clearly mark the concept(s) to proceed with

Documentation of concept evaluation and elimination is significant for traceability as well as knowledge capture and reuse

Fulfill criterion
Do not fulfill criterion
More knowledge needed

Concept Comparison Matrix

Criteria	Concept 1	Concept 2	Concept 3
1.			
2.			
..			
PROS			
CONS			
Comments			

Acitivies to close knowledge gaps:

	Concept 1		Concept 2		Concept 3	
Criteria X	Activity	Result	Activity	Result	Activity	Result
Criteria Y	Activity	Result	Activity	Result	Activity	Result
Criteria Z	Activity	Result	Activity	Result	Activity	Result