A Guideline for Conducting Form Analysis of Branded Products

The Development of a Design Guideline Framework for Product-Producing Companies in a Brand Management Context

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Abstract
This thesis presents the research and development of a framework for creating design guidelines, aimed towards product-producing companies as a part of a brand extension strategy. The thesis answers two research questions:

RQ1: What strategies could be used to analyze visual form and product design as a part of a brand extension strategy for a product-producing company?

RQ2: How can an existing visual brand identity be utilized during the product development process and redefined for new product categories?

The thesis is divided into a literature review and a case application of the presented theories on a real-world product development process. The literature review includes three central frameworks. Firstly, a theoretical framework including theories regarding brand management, product design and form, design syntactics and product architecture is introduced. The theoretical framework also includes product modularity which is specifically included for the case application. These theories are used to create a form analysis framework, which is the second element of the literature review. The third element of the literature review is a framework for how to create design guidelines, based on explicit and implicit design features. The design guideline framework is built from insights and theories found in literature used throughout the literature review.

The case application focuses on the development of a new concept and design guidelines for a modular Autonomous Mobile Robot (AMR) for a case company. The case application utilizes the created theoretical frameworks for a real-world product development process. The created concept envisions the visual brand language of the case company, while also serving as the foundation for the design guideline development.

The form analysis framework is used to understand product design and form on already existing products within a product category. A total of six analyses are introduced, all with their own respective focus on different fields of study and area of application. The form analysis framework investigates three areas of application: Internal and external factors as well as the existing product family of a company. Applying the form analysis framework to the case study show that these methods are suitable for analyzing the visual form of products.

By examining the internal factors of the case company, such as analyzing existing products and prior design guidelines, a format for key design principles can be created. Based on these design principles and insights from the form analysis, the visual brand identity can be transferred to a new product category and described through redefined design guidelines. Findings show that certain design features, such as color and usage of logotype, are the most suitable for acting as identity carriers. Utilizing these can bring cohesiveness to a product portfolio. It can be concluded that the use of explicit and implicit design features is a viable way to holistically describe and articulate product design.

Key words: Product design, design syntactics, form analysis framework, design guidelines, brand management, brand extension, design DNA, modularity, autonomous mobile robots
Preface
This is a master thesis written during the last semester of the fifth year as a part of the Design and Product Development program at Linköping University together with a company who remain anonymous throughout the thesis.

Throughout the thesis many obstacles have been approached and eventually overcome by continuously gathering more knowledge about the chosen research areas and applying it to the project. Exploring an extensive research area and in the end trying to condense the most crucial aspects and utilizing it in a case application has been far from easy. This could not have been done without the assistance from our examiner, supervisors and opponents. Therefore, we would like to thank our supervisor Maria Gustin Bergström for guiding us in our weekly meetings, and our opponents Sofia Holmqvist and Moa Svensson for giving us feedback on our report throughout the thesis. Also, we are very grateful for the insights we got from the many discussions with out examiner Torbjörn Andersson. Lastly, we wish to thank the staff at the company for all the support, motivation and patience throughout the thesis. It is because of them that we have managed to make something that we are very proud of.

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Tomas Andersson

Oskar Castillo Ellström
**Terminology**

**Brand extension**  The activities related to utilizing an existing brand to release a new product (Andersson, 2016)

**Brand identity**  The conjunction between the key beliefs of a brand and its core values (Kapferer, 2008)

**Branded house**  A unified visual recognition and values throughout the entire product portfolio (Andersson, 2016)

**Bus-modular architecture**  The interface is the same for all chunks of the architecture system, with the result of interchangeable chunk positioning on the same architectural system (Ulrich & Eppinger, 2012)

**Category extension**  The brand extension strategy related to extending the brand within a new product category in an existing market (Andersson, 2016)

**Chunks**  “The physical elements of a product (that) are typically organized into several major physical building blocks” - Ulrich and Eppinger (2012, p. 185)

**Current product sign**  The market’s conception of how a product in a market category traditionally is presented (Monö, 1997)

**Design DNA**  The unique characteristics and associations connected to a specific brand that is developed over time (Andersson, 2016)

**Design features**  The building blocks in a product that designers utilize to create a coherence and recognition within product portfolio (Andersson, 2016)

**Design format modeling**  An analysis instrument to identify the visual form of existing product design in a brand management context (Warell, 2001)

**Form element**  A form unit which acts as one of many constituent parts in a perceived physical object (Warell, 2001)

**Form entity**  An active unit within a product that contribute to the semantic and syntactic functionality (Warell, 2001)

**Form functionality**  The effect of a form regarding function and reasoning of a visual appearance related to the component, product or system purpose (Warell, 2001)

**Form syntactics**  The composition and configuration of structural form elements and entities connected to product functionality (Warell, 2001)
<table>
<thead>
<tr>
<th><strong>Functional elements</strong></th>
<th>The operations and transformations within a product design that provides functionality to the product (Ulrich &amp; Eppinger, 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gestalt</strong></td>
<td>The arrangement of parts which in conjunction with each other functions and appears different from the sum of each individual part (Monö, 1997)</td>
</tr>
<tr>
<td><strong>House of brands</strong></td>
<td>The management of several different brands within the same organization, where the various brands are kept separate and distinguishable from each other (Andersson, 2016)</td>
</tr>
<tr>
<td><strong>Integral architecture</strong></td>
<td>Functional elements which are implemented by more than one chunk and the interface between chunks are generally dependent on the primary functionality of the product (Ulrich &amp; Eppinger, 2012)</td>
</tr>
<tr>
<td><strong>Modular architecture</strong></td>
<td>One functional element corresponds to one physical element in a de-coupled interface which also features a well-defined interaction between chunks (Ulrich, 1995; Ulrich &amp; Eppinger, 2012)</td>
</tr>
<tr>
<td><strong>Physical element</strong></td>
<td>“The parts, components, and subassemblies that ultimately implement the product’s functions” - (Ulrich &amp; Eppinger, 2012, p. 184)</td>
</tr>
<tr>
<td><strong>Point of difference</strong></td>
<td>The positive associations with a company brand and products (Andersson, 2016)</td>
</tr>
<tr>
<td><strong>Point of parity</strong></td>
<td>The associations of a product segment that is shared across all competing companies (Andersson, 2016)</td>
</tr>
<tr>
<td><strong>Product architecture</strong></td>
<td>“The scheme by which the function of a product is allocated to physical components” - Ulrich (1995, p. 1)</td>
</tr>
<tr>
<td><strong>Product gist</strong></td>
<td>The overall feeling of a product within a product category (Andersson, 2016)</td>
</tr>
<tr>
<td><strong>Product identity</strong></td>
<td>“A whole with certain functions and properties, intended for a certain purpose” - (Monö, 1997, p. 103)</td>
</tr>
<tr>
<td><strong>Product typologies</strong></td>
<td>The different levels of a product connected to brand recognition in the market (Karjalainen, 2003)</td>
</tr>
<tr>
<td><strong>Sectional-modular architecture</strong></td>
<td>The interface is identical for all chunks constituting the architecture system, but the chunks are not connected to a single element but rather each other (Ulrich &amp; Eppinger, 2012)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Semiotics</td>
<td>“The study of signs and sign systems and their structure, properties and role on socio-cultural behavior” - (Monö, 1997, p. 58)</td>
</tr>
<tr>
<td>Semantics</td>
<td>“The study of the significance or message of signs” - (Österlin, 2011, p. 104)</td>
</tr>
<tr>
<td>Semantic function</td>
<td>“Product function related to the meaning we place, or interpret, into its form” - (Warell, 2006, p. xiii)</td>
</tr>
<tr>
<td>Sign</td>
<td>The underlying significance of any recognizable phenomenon, not only implying the physical form (Monö, 1997)</td>
</tr>
<tr>
<td>Slot-modular architecture</td>
<td>The interfaces between different chunks are different, with the result of non-interchangeable chunks on the same architectural system (Ulrich &amp; Eppinger, 2012)</td>
</tr>
<tr>
<td>Style</td>
<td>A term which describes the distinguishing quality of a shape, structure, design, appearance and type (Chen &amp; Owen, 1997)</td>
</tr>
<tr>
<td>Syntactic functions</td>
<td>The visually connecting or discerning structural compositions and shapes in a design (Warell, 2001)</td>
</tr>
<tr>
<td>Visual brand identity</td>
<td>The holistic visual style that identifies the brand, including brand-typical design features in conjunction with key brand beliefs, values, differentiation and recognizability on the market (Karjalainen, 2003; Kapferer, 2008)</td>
</tr>
<tr>
<td>Visual form</td>
<td>The concept of a visually discernable form limited only to the elements which can be seen (Chen &amp; Owen, 1997)</td>
</tr>
<tr>
<td>Visual style</td>
<td>The aspects of the design entitled to the solid components, graphic elements, textures, colors, and materials (Chen &amp; Owen, 1997)</td>
</tr>
</tbody>
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1 Introduction

According to Ranscombe et al., (2012) the visual appearance of a product is a major influence of the perception of a product and is connected to its chance of success on the market. Warell (2001) states that there is an increased demand in aesthetic appeal and increased understanding of consumer products. Thus, a cohesive and understandable product design is more important than ever.

Further, how the design is managed within a company, as part of a brand, is also of importance. A product design is considered a part of the product identity and heritage, which can be connected to the brand identity. An industrial design can be used to increase the competitiveness on the market by focusing on the product identity and product branding (Warell, 2001).

As a part of the brand management strategy, consistency over product generations is important. A product and brand identity can be used to differentiate a company and to create a cohesive brand recognition over time (Karjalainen & Snelders, 2010). Österlin (2011) expands on this by suggesting that by reusing form elements a company can create a recognition factor for a new product, which in turn strengthens the brand if executed consistently. An expressive function should be in line with the company image, as to not be interpreted as dishonest (Monö, 1997).

1.1 Design Guidelines Introduction

Connected to the industrial design on a strategic level and to brand management is the development of design guidelines. Design guidelines can be described as a set of recommendations which aim to lead a designer towards good practice in design (Interaction Design Foundation, 2019). They can also be used to inform about general strategies regarding changes and modifications in existing design (San Jose Government, 2019). This means that design guidelines can be helpful tools for designers and developers at a company when creating new products. If for instance, the intention is to keep the new product under the same brand, the guidelines will tell how similarities can exist while still making it look different enough to be a new product.

For a product-producing company, it is the design features of the products that are the constituent elements of the design guidelines. Design features can be described as the building blocks in a product that designers utilize to create a coherence and recognition within product portfolio (Andersson, 2016; Hollins & Pugh, 1990; Lewalski, 1988; Warell, 2006; Karjalainen & Snelders, 2010; Ranscombe, et al., 2012; Person, et al., 2007). This can imply the visual form but is not limited to the visual sense alone.

Further, more general guidelines, not necessarily related to a specific company, can often show how design can be used to enable intuitiveness, learnability, efficiency and consistency over time (Interaction Design Foundation, 2019). This does not mean that design guidelines are strict rules which needs to be followed but should be viewed as helpful advice to achieve whatever function is desired. They exist to enable, not restricting, creative thinking, which is a common effect of rules.
1.2 Purpose
The focus of this master thesis is to develop design guidelines as a part of a brand extension strategy for a chosen company. A form analysis framework is created with the purpose to understand product form in a brand management context. Through this framework, the visual brand identity and design of the current product line of the company and its competitors is analyzed. Based on the result from the analysis, design guidelines are developed.

Together with the development of design guidelines, a concept envisioning the design guidelines within the product categories is developed. The objective is to apply the analysis framework to a real-world product development process. Based on the analysis and the insights from the product development process, the design guidelines for the company is developed and evaluated.

1.3 Research Questions
RQ1: What strategies could be used to analyze visual form and product design as a part of a brand extension strategy for a product-producing company?

RQ2: How can an existing visual brand identity be utilized during the product development process and redefined for new product categories?

1.4 Thesis Goals
The thesis aims to develop design guidelines for a case company based on the company’s internal and external factors. The design guidelines are defined in parallel with the product development process of a modular Autonomous Mobile Robot (AMR) for the company. The AMR concept will thus equally envision and define the developed design guidelines. A literature review, including relevant theories and models, is created. This aims to describe how product-producing companies can analyze, understand and articulate product form and how to develop design guidelines for new product categories.

1.5 Limitations
As the aim of the thesis is to develop design guidelines for a new product category aimed at an existing market, it limits the scope of the thesis to the category extension strategy. The form analysis framework is created with this in mind. The design guideline framework is developed to be applicable for industrially designed physical products part of a company product range.

The product development process does focus on the mechanical structure or calculations of the developed concept. It does not focus on the selection of the most suitable production materials regarding cost or performance. It does not focus on the life cycle assessment of the product. Lastly it will not put emphasis on ergonomic factors for the product design.
2 Thesis Structure

The aim of the thesis is to develop design guidelines as a part of a brand extension strategy for a chosen company, as described above. The design guidelines will be based on the development of a concept of a modular autonomous mobile robot platform and a literature review.

The literature review spans over chapter 4-6 including a theoretical framework, form analysis framework and design guideline framework. The thesis structure is illustrated in Figure 1. The theoretical framework presents theories related to product design in a brand management context. The form analysis framework is based on the findings in the theoretical framework. It is designed with the purpose to provide the necessary tools for a product-producing company to understand, analyze and articulate design features of industrially designed products. The design guideline framework presents what aspects and design features to consider and how design guidelines should be used within a company. A conclusion of the literature review is presented in chapter 7.

In chapter 8 the application of the literature review to the product development process of a modular autonomous mobile robot is presented. It shows how the form analysis framework is used and applied to the product development process. It also describes how the design guidelines were created and applied in conjunction with the developed concept. In chapter 9 and 10 the discussion and conclusion of the literature review and the case application is presented.

![Figure 1: Thesis structure describing the content of various chapters and how these are connected to RQ1 and RQ2.](image-url)
3 Methodology

In this chapter the method used to answer the research questions is presented, which are:

RQ1: What strategies could be used to analyze visual form and product design as a part of a category extension strategy for a product-producing company?

RQ2: How can an existing visual brand identity be defined and utilized during the product development process and redefined for new product categories?

A category extension strategy implies that a company aims to compete in a new and often unfamiliar market segment (Andersson, 2016). This means that there is limited knowledge of the products within that category before the product is designed and produced. A company that has the intention to create a cohesive design language also needs to transfer the existing visual brand identity to this new product segment.

To answer the research questions a literature review is conducted, including scientific articles, publications and books. The articles are generally found in databases such as the Linköping university library database, ResearchGate and ScienceDirect using keywords including product design, design syntactics, form analysis framework, design guidelines, brand management, brand extension, design DNA, modularity and user experience design.

The literature review is comprised of a theoretical framework, form analysis framework and design guideline framework. RQ1 is answered by creating the form analysis framework which is a collection of methods described in literature and theories presented in the theoretical framework. By applying the methods on a real-world case, the framework is tested and refined. Some of the methods are directly applicable to the case, and some needs to be modified and adapted to the actual product development process.

By analyzing the existing product range of the company, using the form analysis framework, and transferring them into the new product category a cohesiveness can be achieved. Design guidelines are created for the company based on the design guideline framework. By defining key form elements of the existing product range and applying them on a new concept RQ2 can be answered.

The process is iterative, meaning that the literature review is used as a foundation for the product development, part of the case application. During the application of models and frameworks any missing information or methods become apparent. This showcases how the models can be interpreted and altered, depending on the application area. The interplay between the literature review and the case application of models and framework connected to the product development process is visualized in Figure 2.
Figure 2: The thesis method illustrated as an iterative process between the literature review and the case application.
4 Theoretical Framework

In this chapter the theories and models related to the development of the form analysis framework and product design are presented, see Figure 3. In this thesis brand management is connected to the strategic level of design by linking the design language of a new product to the brand of a company. Fundamental theories related to product form and communicative design is introduced. This includes topics such as gestalt, product semantics, visual composition of a design, material properties and user interaction. The concept of design syntactics is also introduced which defines the structure, functioning of form, composition and content of a visual form. Lastly, product architecture is presented, meaning the arrangement and structure of functional elements.

Figure 3: The relationships between the fundamental aspects of the theoretical framework connected to the form analysis framework.
4.1 Brand Management
An organization should take strategic brand management into consideration when designing new products, as every new product that is released on the market is a representation of the company and its values. There are two ways to manage a product-producing company’s portfolio: Branded house and House of brands. The former refers to a unified visual recognition and values throughout the entire product line-up. The latter refers to the management of several different brands within the same organization, where the various brands are kept separate and distinguishable from each other. (Andersson, 2016; Kapferer, 2012)

In this thesis the aim is to develop design guidelines and a product that is connected to the existing brand of a company. Therefore, only the branded house strategy is considered. When applying the branded house strategy, a company needs to consider three main aspects: The product heritage (previous products), the current product portfolio and competitors on the market (Andersson, 2016; Monö, 1997).

4.1.1 Brand Extension
Brand extension refers to when a company utilizes an existing brand to release a new product (Andersson, 2016; Keller, et al., 2011) There are several ways for a producing company to extend the brand. Andersson (2016) summarizes the research of the area and identifies five categories: Category extension, Brand line extension, Vertical extension, Redesign and Revitalization.

- **Category Extension** refers to the activities of a company that aims to compete in an existing market by extending the brand within a new category
- **Brand Line Extension** refers to the activities of a company that aims to expand the brand within the same market
- **Vertical Extension** is similar to Brand line extension, but with a focus to release product lines within different market segments (such as premium and low-cost alternatives)
- **Redesign** is when a company makes minor changes to the design of an existing product. It can be used to increase competitiveness on the market as well as to closer connect a product or product line to the brand values
- **Revitalization** is similar to redesign but with a more radical approach, which on a larger scale deviates from the existing design DNA

4.1.2 Visual Brand Identity
According to Phillips, et.al. (2014) and Karjalainen (2003) a company, just like a human, can be described with specific characteristics. It can be thought of as the holistic visual style that identifies the brand. This is what is defined as the Visual brand identity. Kapferer (2008) also mention the term Brand identity and describes it as a conjunction between the key beliefs of a brand and its core values.

Andersson (2016) states that there is a connection between design features and brand values, which is shared across the product portfolio. Kreuzbauer and Malter (2007) expands on this by claiming that to create this brand identity or brand value product design is a requirement. Thus, these factors have their defining elements which are as follows:
- The brand-typical design attributes heavily influence our recognition of a new product. Design facilitates product and brand categorization and alters the consumers beliefs about these.
- The design elements connect information about the functions and how the consumer may interact with it physically.
- Higher level of aesthetically pleasing design lead to a more positive brand evaluation.

Moreover, Kapferer (2008) elaborates that there are numerous ways to describe what identity means in different contexts, and to help a company to define the brand identity the following questions could be answered:

- What is the brand’s vision and aim?
- What makes it different?
- What need is the brand fulfilling?
- What is its permanent nature?
- What are its values?
- What is its field of competence? Of legitimacy?
- What are the signs which make the brand recognizable?

Visual brand identity can thus be described as a combination of many different factors. By implementing a brand-typical design and design features, a company can tie together the visual style, key beliefs and core values in the product which creates a differentiation on the market and a recognizability to the user. Since it varies between different contexts it is difficult to state exactly what visual brand identity should be. However, in this thesis the focus will be on the company’s design elements connected to core values.

4.1.3 Consumer Processing of Visual Brand Identity

The most commonly used design elements are stored in the consumers long-term memory after continuous exposure making them essential for a brand (Kreuzbauer & Malter, 2007). This is further enforced by Phillips, et al. (2014) who states that continuous exposure to visual and verbal information can be stored in our memory as Schemas, meaning that the outcome of familiar experiences will be expected to stay the same. When a consumer is shown new information, familiarity will make the processing require less effort which is appreciated by the consumers. This fluency of processing the new information will unconsciously be linked to the object itself.

Warell (2015) also expands on this by stating that brand recognition is created through consistent use of similar visual form elements or design cues. Continuing, Kreuzbauer and Malter (2007) discuss the phenomenon of when an individual sees design elements which are very familiar it will instantly trigger memories associated with the brand. Depending on the individual’s previous experiences, it can have either positive or negative effects for the brand recognition.

Considering this, it can be concluded that consumer processing of the visual brand is an important aspect to take into consideration when designing new products. By carefully and purposefully creating products which supports the association of positive brand experiences, the product can be easier to understand and interpret. It also generates a connection of the product to current and previous product portfolios and brand values.
4.1.4 Product and Brand Recognition

One theory mentioned by Karjalainen (2003) discusses different product typologies. The author introduces two typologies, sub-ordinate and basic. The sub-ordinate level implies that there are features which makes it possible to tell different brands apart from each other. The basic level instead focuses on features which are always present in products within a certain category. Thus, products can be recognized on different levels. This is similar to the concept of point of difference and point of parity, where the former means the positive associations with a company brand and products, and the latter means the associations of a product segment that is shared across all competing companies (Andersson, 2016; Keller, et al., 2011).

In addition, Warell (2015) mentions a similar procedure of recognition. He describes three reference types each with a different meaning; Categorization (What is it?), Characterization (How is it?) and Valuation (Why is it? / What does it infer?). For instance, first a product will be identified as belonging to a certain product category, e.g. a vacuum cleaner. Secondly, the products characteristics are identified, e.g. powerful. Lastly, the connection to the brand is made and associations from prior experiences will surface.

The theories regarding basic level, point of parity and categorization as mentioned above are closely related to the term current product sign, which is defined by Monö (1997) as the market’s conception of how a product in a market category traditionally is presented. A similar concept is product gist, defined by Andersson (2016) as the overall feeling of a product within a product category. If a product strays too far from the current product sign it might not be recognizable within the product category (Monö, 1997).

Further, Phillips, et al. (2014) introduces a theory which states that keeping dergency to a minimum from the brands standards is beneficial. This is due to changes having the potential risk to upset the consumers since changes in products causes them to not correlate with what the consumers are used to. However, over time, smaller changes can be accepted and then become part of the brands standards.

Moreover, Karjalainen (2003) and Kreuzbauer and Malter (2007) mentions how making new products feel part of the brand through the usage of explicit design elements is a way to extend the brand. This will make the consumers start thinking about a certain brand even when they see a completely new product. If prior associations already were positive the view on the new product will be more likely to be positive as well (Phillips, et al., 2014). In contrast to this Kapferer (2008) points to the fact that using the same brand name for new products might not be the best decision. If the plan is to perform a vertical extension and doing so to create lower quality products than normal, then making a new brand could be preferable. This is because the lowered quality alternative could affect the parent brand (Kapferer, 2008).

Another point of view is that one standalone element might not be enough for a consumer to associate it with a brand (Phillips, et al., 2014). The authors mention how it is difficult to make one element by itself be linked to the brand. By coupling several design elements together, this desired effect is easier to achieve.

Further, there are two aspects of identity. Either an identity is similar to others or different to others. This mean that identity by itself, without any point of reference is useless. This also means that the sequence of identification only happens if the similarities or differences are significant. (Warell, 2015)
Based on these findings, it can be concluded that:

- By analyzing and understanding the product segment and product category a company can better define what will differentiate the product on the market and at the same time make it part of the product segment.
- A designer should be aware of how the current product sign is represented within the product category, and understand in what way it will affect the market’s perception of a novel design if it strays from the traditional view of the product category.
- It is in the conjunction of cohesive design features in the brand- and market context that communicates the product identity and purpose to the perceiver.

4.1.5 Design DNA

Design DNA is defined as the unique characteristics and associations connected to a specific brand that is developed over time (Andersson, 2016; Person & Snelders, 2009). As the term DNA refers to a heritage and to the evolution that occurs in nature, it also implies that this evolution must have a beginning. Every brand needs to start somewhere and as stated by Kapferer (2008) it implies that early on any brand has the potential to go in almost any direction. By consciously defining the design DNA and transfer that within the product lineup a company can over time facilitate a brand recognition on the market (Andersson, 2016).

Brand value can be communicated by utilizing visual design features which allows customers to attribute meaning to the brand related to heritage and character (Warell, 2015). Further, Warell (2015, p. 2119) states “design elements of one product category can be transferred to a new product category within the same brand by modifying key characteristics of product-shape attributes.”

Through the introduction of product successions based on the same design DNA, the freedom of which direction to take decreases. All this while the brand itself gains conviction and takes shape, which limits its actual territory of operation. Thus, it depends on what the company decided the brand should be in an early state that affects any product later associated with the brand. The typical products endorsed by the brand, the name itself, any symbol or logo and the country of origin as well as advertisement and packaging must be taken into consideration. (Kapferer, 2008)

By shaping a product, not only are the visual appearance, appeal and aesthetics affected, but also the cognitive understanding of the products. Warell (2001) defines a form entity as an active unit within a product that contribute to the semantic and syntactic functionality, these are further discussed in 4.2. A form entity is thus an active part of the product form which provides functionality through the subjective perception of the user without any transformative abilities. This means that the structural configuration of a form element remains unaffected after user interaction.

4.2 Product Design and Form

Everything around us communicates, directly or indirectly. A product has a language that the user perceives, based on the interpreted sign (Monö, 1997). This language is written in the product design. Design is an extensive term, used differently in connection to various industries and markets. Design is derived from the Latin word ‘designare’ which means to mark out, designate, denote (Monö, 1997). This in relation to the aesthetics of a design, which is defined
by the same author as the effects of the product form on the human sensations. This denotes the way a product form and characteristics affect our perception.

Chen and Owen (1997) defines form as a term which describes the general shape, structure, design, appearance and type of an object. A product form is rarely made as a coincidence. Forms are often related to specific, underlying properties of the design (Österlin, 2011).

Warell (2001) further expands on the term form by introducing the term form element, which is defined as a form unit which acts as one of many constituent parts in a perceived physical object. A form element is not to be defined as equal to a component, rather it can be identified on different levels of a product structure, ranging from a single part to a component, assembly or entire product, depending on the system boundary and the interaction of the elements (Warell, 2001). Chen and Owens (1997) further elaborates with the term visual form as the concept of a visually discernable form limited only to the elements which can be seen.

Chen and Owen (1997) also defines the term style as a term to be used when describing the distinguishing quality of a shape, structure, design, appearance and type. Further, the author defines the term visual style as the aspects of the design entitled to the solid components, graphic elements, textures, colors, and materials.

By shaping a product, not only are the visual appearance, appeal and aesthetics affected, but also the cognitive understanding of the products. Warell (2001) defines a form entity as an active unit within a product that contribute to the semantic and syntactic functionality. A form entity is thus an active part of the product form which provides functionality through the subjective perception of the user without any transformative abilities. This means that the structural configuration of a form element remains unaffected after user interaction.

Signs are normally related to visual signs. The impression of the world around is mostly dominated by our vision, and the word sign is therefore often interpreted as something you can see. Monö (1997) defines a sign as the underlying significance of any phenomenon which does not directly imply the physical form. A sign can be interpreted by more senses other than our vision, including hearing, smelling and feeling (Monö, 1997). Other senses include aspect such as the sense of balance, muscular and joint system and temperature (Österlin, 2011). A correlation between different signs, regarding their effect on various senses, should exist for the understanding of a form (Monö, 1997).

Semiotics is defined by Monö (1997, p. 58) as “The study of signs and sign systems and their structure, properties and role on socio-cultural behavior”. Österlin (2011, p. 104) presents a similar definition: “The study of signs, their structure and usage”. Product semiotics can in connection to a physical artifact be explained as the signs we can interpret from the product we interact with (Monö, 1997).

Semantics is part of the semiotic area, but with an emphasis on the underlying message of the sign, defined by Monö (1997, p. 167) as “The study of the signs message” or similarly by Österlin (2011, p. 104) as “the study of the significance or message of signs”. A sign can be seen as the intersection between the sender of the message, the product and the receiver based on descriptive, expressive, exhorting and identifying messages (Monö, 1997).
4.2.1  Gestalt

The gestalt expression considers the conjunction of different aspects and parts of a design and how they influence the user experience of a form (Monö, 1997). The same author defines this term as an arrangement of parts which in conjunction with each other functions and appears different from the sum of each individual part. A gestalt is according to Monö (1997) not limited to physical forms. Anything we can perceive as a whole can be described as a gestalt.

Every experience must be interpreted by the human mind through the available senses. The brain always chooses the easiest way to interpret this by creating patterns and groupings, often in relations to previous experiences, expectations, attitudes and motives (Österlin, 2011). This cognitive ability of grouping and simplifying a shape is the foundation of the gestalt principles. These principles are based on that the human mind tend to group and sort objects as easily as possible (Monö, 1997). This is according to Österlin (2011) part of the human frame of reference, which filters and organizes the surrounding impression of the human mind.

Commonly discussed gestalt principles are described by Monö (1997) and Johnson (2010) as:

- **Proximity**: Objects close to each other is grouped together
- **Symmetry**: Symmetrical elements are grouped together
- **Similarity**: Sorting objects based on their common properties
- **Area factor**: A smaller area of an enclosed form is more easily identified than a larger area
- **Figure/Ground**: Our mind separates objects on an interpreted image into a foreground and background, based on which feature has our primary attention. Closely related to the area factor, where small areas are identified to be placed on top of a bigger area, rather than be seen as a hole.
- **Continuity/The good curve**: Whenever possible, the mind creates a connection between forms that follow a curve, rather than seeing them as disconnected
- **Common fate/Common movement**: Elements moving together is interpreted to belong together
- **Closure/The inclusion factor**: The mind tends to see things as an enclosed object rather than separated lines
- **Experience factor**: Our previous interaction with objects and signs determine what we discern of the form

4.2.2  Semantic Functions

All products send a message to the user, no matter if it is the intended message or not. The visual perception of a form can be categorized into non-interpretative and interpretative mode: The first meaning the experiential, sensuous, appreciation of a form, i.e. the initial impression of a form without the search of meaning and purpose of the form. The latter meaning the semiotic attributes and meaning of the form, i.e. the conscious understanding of the form based on the interpreted contextual usage and purpose. (Warell, 2001). The message can according to Monö (1997) be characterized as describing, expressing, exhorting and identifying. Österlin (2011) describes a similar topic: Product expression. This refers to the ability of a product to be able to express character, identity and function.

**Semantic function: To describe**

A sign can as a semantic function be used to describe the functionality of a product, based on the interpreted gestalt (Monö, 1997). Sometimes it is enough to incorporate a small detail which
communicates the intention to a user and other times it is better to design a feature that boldly deviates from the rest of the product, to gain the user’s attention (Österlin, 2011). Monö (1997, p. 84) presents a hypothesis: “The better known the sign, the greater the number and degree of variations it can stand”. This implies that a strong sign of a product feature allows other features to be altered, without the risk of losing the original message.

**Semantic function: To express**
Expressive semantic functions are, according to Monö (1997), used to communicate a quality or property of a product, e.g. heavy, compact or fragile, and can also display emotional properties, like happy or angry. (Monö, 1997).

Character is related to the expressing semantic function. The product character can be described by polar adjective pairs, e.g. hard and soft or expensive and cheap. (Österlin, 2011). Chen and Owen (1997) further uses these polar adjective pairs as a part of the formation of visual styles by grouping different design features as: form elements, joining relationships, detail treatments, materials, color treatments and textures. The definition of a form entity by Warell (2001) emphasizes the semantic interaction and functionality provided by an object form, which can be described through e.g. proximity, symmetry, rhythm, proportion, balance, harmony and contrast (Warell, 2001).

**Semantic function: To exhort**
Exhorting semantic functions are intended to provoke a reaction from the recipient (Monö, 1997). The product form or gestalt is a key factor for product understanding, and by creating a coherence to user expectations, frame of reference and needs the exhorting semantic function can be easily recognized and utilized (Österlin, 2011). Monö (1997) further develops this argument, stating it is crucial that the various exhorting functions are cohesive to achieve the desired effect. By using the gestalt impression, the exhorting semantic function in connection to a feature represented by a strong sign, the semantic functionality can be strengthened (Monö, 1997).

**Semantic function: To identify**
A products’ identity is defined by Monö (1997, p. 103) as “a whole with certain functions and properties, intended for a certain purpose”. By consciously and carefully choosing cohesive identity carriers, a heritage and context can be conveyed externally (Österlin, 2011). An identifying property is the products origin, purpose, affiliation, placing and category, which could as an example include logotypes, product names, trademarks, forms, colors, packaging, figures, arrangements and icons (Monö, 1997). Consistent use of design features generates a powerful and united brand image which differentiates a company from its competitors (Österlin, 2011).

### 4.2.3 Syntactic Functions

Syntactic functions are based on the concept of syntax, defined by Monö (1997, p. 168) as “The study of the relations of signs to other signs”. These functions can be described as the visually connecting or discerning structural compositions and shapes in a design. In other words, these functions are dependent on the syntactic relationship between different form entities part of the same physical design. It can also be applied across different products. It is always dependent on the context in which the form or shape resides and is closely connected to the gestalt principles. In the same way the semantic functions communicate an expression or property of a form based on the experience of the observer, the syntactic functions describe the connection
of form entities (Warell, 2001). This might be translated into a feeling of coherence within the design.

Warell (2001) describes five syntactic functions: discerning, connecting, referring, uniting and balancing, see Figure 4. The discerning syntactic function separates two form entities from each other. This can be done by visually creating the two entities fundamentally different. This could imply the usage of strong colors or fundamentally different shapes in design features.

![Image of syntactic functions](image)

*Figure 4: Warell (2001, p. 101) illustrations of the syntactic functions.*

The connecting syntactic function creates visual couplings between the form entities, meaning that they partly, but not completely share specific visual properties inherent to each of the entities. An example is the usage of color and form of two form entities part of the same design. The referring syntactic function creates a connection between two different products by a visual relationship of specific form entities. Uniting syntactic functions are similar to referring, with the difference that the two form entities are part of the same design and shares a common gestalt. Balancing syntactic functions create a visual harmony in the design by visual counteraction. This could imply the usage of symmetry, contrast and rhythm part of the product gestalt. (Warell, 2001) Examples of these syntactic functions are illustrated in Figure 5.

![Image of Husqvarna product range](image)

*Figure 5: Illustrations of the different syntactic functions presented by Warell (2001). The depicted models are part of the Husqvarna product range.*
By consciously considering what syntactic functions to utilize and how this will affect the user perception of the product, a design can therefore become easier to understand and achieve a visual congruence.

4.2.4 Visual Composition

Stebbing (2004) investigated the occurrence of defining terms for visual composition within art and design literature. Through the literature review Stebbing found that contrast, rhythm, balance, proportion were four commonly used terms to define a visual composition. Additionally, he found that movement and expression were two terms commonly used to define a perceptual effect of this composition. (Stebbing, 2004)

Contrast is described by Stebbing (2004) as the perceptual difference between two form elements, visually defined by the contrast between lines, shapes, forms, orientations, sizes, tones, numbers, dimensions, transparencies and weight. Rhythm can be described as the reoccurrence of more than two form elements in structural patterns, visually represented with repetitions, rotations, reflections and glide reflections. This is believed to be useful to make the grouping of elements stand out as more exciting (Tjalve, 1979). Further, Stebbing (2004) describes balance as the unresolved tension and relationship between two form elements, visually represented by the relationship between size, tone, color, intrinsic interest, shape, location and isolation. Tjalve (1979) mentions visual balance which expands on this. He describes how two elements, if close enough to each other, feel like they belong together. Proportion can be described as the spatial relationship between two form elements in a visual composition by measuring the ratio of the constituent elements (Stebbing, 2004).

Examples of the visual representations of how contrast and proportion can be used to create balance is presented in Figure 6.

![Figure 6: Larger objects are interpreted as heavier than small ones, a darker tone also feels heavier](image)

Additionally, Warell (2001) brings attention to different types of form entities in visual product form. There he describes that in a physical product form, a total of four types of configurations of form elements exists. These four are; distributed, enclosed, discrete and composed, see Figure 7 for examples of such form entities. If form elements appear as distributed it implies that they are geometrically extended across other form elements. In contrast, enclosed implies they are geometrically enclosed within another form element. Further, discrete implies that a form entity is realized by a single form element while composed means a grouping of form elements is present. Thus, a physical product form cannot be both distributed and enclosed or discrete and composed simultaneously.
4.2.5 Material Properties and the Choice of Material

Karana et al. (2007) conducted a study regarding the aspects which product designers take into consideration while selecting materials such as manufacturing of materials, technical-, economic-, ecological-, sensorial- and intangible properties, see Table 1. Apart from the obvious factors such as technical and sensorial characteristics of a material an interest towards more intangible properties have risen. This is, according to Karana et al. (2007) because of the increase in product and material consumption which leads to higher competition on the market. Thus, utilizing the intangible attributes such as using metal to indicate durability and precision can be effective to link a meaning to the products.

Table 1: Different aspects to take into consideration during the material selection process, as described by Karana et al., (2007, p. 1085).

<table>
<thead>
<tr>
<th>Technical properties</th>
<th>Density, conductivity, strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing of materials</td>
<td>Producing, ease of manufacturing</td>
</tr>
<tr>
<td>Economic properties</td>
<td>Cost, availability</td>
</tr>
<tr>
<td>Ecological properties</td>
<td>Recyclability, sustainability</td>
</tr>
<tr>
<td>Sensorial properties</td>
<td>Colors, texture, smell</td>
</tr>
<tr>
<td>Intangible properties</td>
<td>Emotions, meanings, effects, trends</td>
</tr>
</tbody>
</table>

Furthermore, with the rise of intangible characteristics of materials Karana et al. (2007) mentions that product designers have several questions that needs to be answered during the materials selection process. For instance, they might need to know if the materials are suited for the target group or what kind of associations a specific material may evoke. Material selection and surface finish is related to the product color. Color patterns can be used for identification, and a combination of colors can create a stronger color identity and can also communicate the purpose of the product (Monö, 1997).

Karana, et al. (2007) also puts emphasis on that designers prioritizes different qualities in materials depending on how far into the design process they are. Early on the intangible characteristics of materials is more important, meaning appearance, texture, color and surface finish are deciding factors. Later, when detail design is the focus, the technical properties become more important. They then look at cost for manufacturing and overall production. However, no matter at which stage the product development is in, the availability factor is always important (Karana, et al., 2007).
4.3 Design Syntactics

Design syntactics is defined by Warell (2001) as a constitutive framework of three conceptual elements: *form functionality, form syntactics* and *design format modeling*. The framework is used to define the structure, functioning of form, composition and content of a visual form design (Warell, 2001). The design syntactic framework is considered a suitable characterization of a physical design, as it covers the key aspects related to a product form.

Form functionality denotes the effect of a form regarding function and reasoning of a visual appearance. Functionality is related to the component, product or system purpose. Without a set purpose and meaning, the existence of a product form is not motivated. During a design process of an aesthetic form the designer must motivate the chosen form based on the required form functionality and design principles. (Warell, 2001)

Form syntactics denotes the composition and configuration of structural form elements and entities, delivering the required effect and function. Form syntactics could thus be described as the configuration of, and relationship between, physical form elements. The form elements can be described with attributes such as proportion, orientation and shape, although these attributes do not say much in isolation as these attributes need a frame of reference. This reference is described by the composition and configuration of these form elements, which can also be described as their relationship. (Warell, 2001)

Design format modeling can be used as an analysis instrument to identify the visual form of existing product design in relation to marketing strategy, corporate values, target users, technology, brand philosophy and product history/portfolio. It can also be used as a specification and synthesis tool to create and manage guidelines to describe the intent and purpose of existing forms. It specifies how a design format of a product family is influenced by the existing product families, the product styling history and external factors, such as trend, styles and competitors, see Figure 8. (Warell, 2001)

4.3.1 External factors

The company’s external factors are described by Warell (2001) as factors which are not owned by one company. Instead these are available for any product-producing company and can be put into use when desired. These factors consist of trends, current styles and design used by competitors. The external factors’ importance lies in the fact that to create a design which fits well into a market segment it should either blend in well or be very different. To achieve that, an understanding for the existing design already established must be gathered. This is especially true when the goal is to enter a market where no prior experience exists. Thus, these factors can aid in the development of knowledge required to distinguish a well-design product of one type to a less thought through one.

4.3.2 Internal factors

In contrast to external factors, the internal ones are brand specific resources (Warell, 2001). One example of this is the product styling history within the company. By analyzing prior design, the new products can be made to look reminiscent of prior products which ties them together to the brand. Thus, it is relevant to keep these internal factors in mind when developing new products with new design if they are to be part of the same product family. However, even when diverging into new product segments it can be desirable to keep certain design elements to help customers have an easier time identifying the new products as part of the brand.
4.3.3 Product Family
Generally, product-producing companies have at least one product family consisting of several different products. This is according to Warell (2001) one of the factors to be used to influence the creation of a new design format. These products are most likely built up using common design elements but used in different configurations, hence they seem part of the same family. This in turn gives feedback to the design format which the products originate from to enable further development and refinement.

4.4 Product Architecture
This section describes relevant theories of product architecture and modularity, which is two aspects that describes the product structure, functional and physical elements and the interfaces between these.

4.4.1 Architecture
Ulrich (1995, p. 1) defines product architecture as “the scheme by which the function of a product is allocated to physical components”. In more detail this means that the product architecture is defined by the arrangement and structure of functional elements as well as the schematic connection between functional elements to physical components, including the interface between said components (Ulrich, 1995).

Functional elements can be described as the operations and transformations within a product design that provides functionality to the product, and therefore also contribute to the products performance (Ulrich & Eppinger, 2012). The arrangement of functional elements, also called the function structure can be done on several different levels of the product structure (Ulrich,
At the top level this could imply the main purpose of the product, e.g. a pencil's main purpose is to transfer lines and shapes from the user's hands to a piece of paper. Looking at the pencil at a more detailed level, the functional elements could include provide grip, replace pencil lead, eject pencil lead, distribute forces and so on.

A physical element is defined as “… the parts, components, and subassemblies that ultimately implement the product’s functions” (Ulrich & Eppinger, 2012, p. 184). Integrated physical components thus results in the creation of the functional elements of the product (Ulrich, 1995). The difference between a functional and physical element is therefore that the functionality is independent in the physical form. An example: if the function is to expand the loading capacity of a car, the physical components which provides this functionality can look fundamentally different. Both a roof box and a trailer can provide this function.

By grouping and organizing physical elements into physical building blocks chunks are created, which is what ultimately implement the product function (Ulrich & Eppinger, 2012). Chunks are defined by Ulrich and Eppinger (2012, p. 185) as “The physical elements of a product (that) are typically organized into several major physical building blocks”. The interface between two physical components or chunks could both imply a geometric interaction (such as the interface between a mounting bracket on a support structure) or a non-contact interaction (such as wireless transfer of data between a sensor and a computer) (Ulrich, 1995).

4.4.2 Modularity

Product modularity can today be used to better adapt to the fast-paced globalized market. Modular architectures allow a company to more easily adapt to market demand on time, without the difficulties of overwhelmingly complex production systems. Modularity also affects several aspects of the flexibility of a product including product upgrading, add-ons, adaptation, wear, consumption, flexibility-in-use and reuse. (Ulrich & Eppinger, 2012). Further, product modularization affects the industrial design as the development must consider how new design features will be incorporated into the modular system and the product portfolio (Andersson, 2016).

Kashkoush and ElMaraghy (2017) defines a module as a structurally independent element or sub-assembly within a sub-assembly with clearly defined interfaces. Hvam, et.al. (2017) states that the natural goal of product development is to include a high number of modules where each of the modules are described in detail. However, it is also stated that this does not necessarily mean it always is the best option for all manufacturers (Hvam, et al., 2017). Instead, it matters more which kind of company is dealing with the modularization and what type of manufacturing is common in said industry.

There are several methods for designing modular products and these are classified into two groups, function-based and matrix-based. The former works by identifying modules by mapping the functional decomposition of a product to its physical architecture. The method is lacking in the fact that it cannot effectively address the interfaces between product physical elements. The latter identifies modules by reconfiguring the product design structure matrix which represents the product architecture. (Kashkoush & ElMaraghy, 2017)

Products can be designed with a strictly modular architecture or a strict integral architecture, but more commonly a combination of the two polar opposites is used (Ulrich & Eppinger, 2012). An integral architecture typically features functional elements which are implemented
by more than one chunk and the interface between chunks are generally dependent on the primary functionality of the product (Ulrich & Eppinger, 2012). An integral architecture thus implies that a multitude of functional elements are created by several coupled physical components each, as compared to a modular architecture where one functional element corresponds to one physical element in a de-coupled interface (Ulrich, 1995). A modular architecture also typically features a well-defined interaction between chunks (Ulrich & Eppinger, 2012).

A coupled interface between two physical components means that changes made to one of the components will most certainly require a change in the other, whereas a de-coupled interface allows the components to change independently to each other (Ulrich, 1995). An example of a coupled interface is between the display of a phone and the phone chassis. Changing the dimensions of the display requires that the phone chassis will have to be reconstructed too. A similar but opposite example of a de-coupled interface between a computer display and a stationary computer. Any changes made to the computer display will not affect the computer, given that the interface remains the same.

Product variety is defined as the number of products a company can produce within a given time period. Components standardization means that the same component can be used in several products which benefits the ability of a company to have a high degree of product variety. A modular architecture is an efficient approach to achieve component standardization, as it enables that the de-coupled interface is identical across different products. (Ulrich, 1995) Additionally, by implementing modular chunks, the flexibility during the product development process is strengthened, as changes can be made that does not alter the preconditions for the entire system. (Ulrich & Eppinger, 2012)

4.4.3 Modularity Categories

Ulrich and Eppinger (2012) defines three types of modular architectures: slot-modular, bus-modular and sectional-modular:

- A slot-modular architecture means that the interfaces between different chunks are different, with the result of non-interchangeable chunks on the same architectural system (e.g. car radios, camera lens mountings)
- A bus-modular architecture means that the interface is the same for all chunks of the architecture system, with the result of interchangeable chunk positioning on the same architectural system (e.g. PCI-e slots on a motherboard, shelve systems based on rails)
- A sectional-modular architecture means that the interface is identical for all chunks constituting the architecture system, but the chunks are not connected to a single element but rather each other (e.g. floor decking systems, Lego, piping systems)

An illustration of the differences between an integral architecture, slot-modular architecture, bus-modular architecture and sectional-modular architecture is shown in Figure 9.
Figure 9: An example of integral architecture, slot-modular architecture, bus-modular architecture and sectional-modular architecture, as depicted in (Ulrich, 1995, p. 426)
5 Form Analysis Framework

The form analysis framework describes various methods a product-producing company can use to better understand and motivate the design of a physical product. The framework is mainly based on presented theories in the literature review chapter. Some of the methods are described as found in literature, meaning no alteration or adaptation has been made compared to how it is described originally. Other methods are altered or combined, based on findings in the theoretical framework. Six different methods are presented: Product category analysis, semantic functionality analysis, syntactic functionality analysis, design format analysis, proportion orientation and shape analysis and architecture analysis.

5.1 Product Category Analysis

The product category analysis is meant to identify and specify form elements of a product segment. It is based on various findings in literature, meaning it is based on both existing methods as well as theoretical concepts.

**Purpose:** The purpose is to understand the basic prerequisites of a product category, as to better determine the current product sign and commonalities within the product segment. It is also meant to enhance the understanding of the differentiating features of competing products. This knowledge may be used to better define what the requirements are within the category and articulate how the company aim to position themselves on the given market. The analysis is suitable for understanding external factors.

**Description:** The product category analysis method is created with the purpose of analyzing the form of a specific product category. Two main levels are investigated: The *basic level* and the *differentiating level*. It can favorably be used during the early stages of a category extension strategy to analyze competing products on the market. The method is based on the findings in the literature review, including product typologies (Karjalainen, 2003), point of difference and point of parity (Andersson, 2016), category recognition (Warell, 2015), current product sign (Monö, 1997) and product gist (Andersson, 2016).

On the basic level the product category gist and associations, general features and categorization is analyzed (Andersson, 2016; Karjalainen, 2003; Warell, 2015). This includes basic design features such as shape, form and silhouette. Andersson (2016) describes a model to identify commonality within the product segment based on the product gist, see Figure 10. The model is founded on the principle of layering pictures of products within the same product category to better understand the basic shapes, silhouettes and current product sign of the products.

The gist analysis model introduced by Andersson is well suited when the products are similarly configured, based on the shape, proportion and scale. The model is harder to implement on a product segment which does not feature this similarity, especially considering scale and proportion. For that purpose, a more subjective approach is developed. The recommendation in this case is to observe and analyze the competing products main form features, such as shapes, forms and silhouettes. In this case the three reference types of category recognition can be used, meaning product categorization, characterization and valuation, as described by Warell (2015). Based on this analysis, general orthogonal representations of what can be observed can be generated for the product segment, see Figure 11.
Figure 10: The basic level analysis, or product gist analysis presented by Andersson (2016, p. 29) featuring four different approaches by layering pictures of competing products.

Figure 11: An illustrative example of the basic level analysis of a product segment which features products with different basic scales and proportions and dominating forms. The subjective representations are illustrated in orthogonal views for various configurations.
On the *differentiating level* the analysis is developed based on the discerning features of each company, related to the concept of sub-ordinate recognition (Karjalainen, 2003), point of difference (Andersson, 2016) and valuation (Warell, 2015). Here the proportion, scale, orientation, surface, ordering and texture are examples of design features which could be examined. The examination of the design features of the products is objective in that sense that it articulates and points out the visible features of products within the category, see Figure 12. The analysis of the examination, i.e. the evaluation of what features is regarded as differentiating, is on the other hand a subjective assessment.

![Figure 12: An illustrative example of the product category analysis on the differentiating level for a product part of a market segment.](image)

**Expected result:** The result from the gist model on the basic level is considered to be an objective representation of the product segment, which provides a basic understanding of how the current sign might be interpreted on the market. It also shows how the product might be categorized, based on the visual representation (Warell, 2015). If the product segment is well represented and has a long history on the market, the result from the model can be a representation of the user’s perception of the product through memories stored as schema, as described by Phillips, et al. (2014).

The subjective analysis on the basic level of the product category (as depicted in Figure 11) can visualize and articulate reoccurring features, with the purpose to define what commonality can be found. This commonality might not be a true representation of the current product sign, but it can provide a basic understanding of the product design.

The analysis on the differentiating level provides an overall feeling of what design features competitors are utilizing to distinguish themselves on the market. This information could be used to avoid creating a new design that might be in violation of a certain company intellectual
property or patent. It can also create a deeper understanding of what form languages are preferred within the product category.

5.2 Semantic Functionality Analysis

The semantic functionality analysis is meant to generate an understanding of the messages a product can communicate based on the product expression. The method is mainly based on the different semantic functions described by Monö (1997).

**Purpose:** The purpose of the semantic functionality analysis is to better understand an existing product or forms communicative qualities. The analysis is based on visual perception, part of the interpretative mode, meaning the search of the underlying purpose and function of the form entities part of the design (Warell, 2001). By structuring the impression of the form entities into describing, expressing, exhorting and identifying semantic functions, the purpose of the form entities can be described.

**Description:** The semantic functionality analysis can be used to articulate the perceived impression of form entities and design features of an existing product. The design can be both external or internal for the company in question. This means that if the product is part of the competitor product range, it can be used to appreciate the form entities of the design, as to better understand what differentiates various products and companies from each other. If the product is part of the internal product range of the company, the analysis can be used to define key attributes of the design which could be transferred to new product categories.

Four semantic functions are analyzed: describing, expressing, exhorting and identifying, as introduced by Monö (1997), see Table 2. These semantic functions can be considered in conjunction with the perceived or intended product expression, categorized by Österlin (2011) as the *product function* (related to describing semantic function) *product character* (related to expressing semantic function) and *product identity* (related to identifying semantic function).

<table>
<thead>
<tr>
<th>Product A</th>
<th>Describing semantic function</th>
<th>Expressive semantic function</th>
<th>Exhorting semantic function</th>
<th>Identifying semantic function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form entity 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form entity 2</td>
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<td></td>
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<tr>
<td>Form entity 3</td>
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<tr>
<td>Form entity n</td>
<td></td>
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</tr>
</tbody>
</table>

Table 2: Semantic functionality analysis
To perform the analysis, the development team sections the design into form entities. The division is based on subjective assessments of the constituent elements and will vary depending on the analyzed product. A basic approach could be to section the product based on the identified components. The components must then be easily discernable from each other, and clearly exhibit different semantic properties. If not, this approach is not recommended. In this case it is better to analyze the product based on different levels, based on the reference types introduced by Warell (2015): Categorization (What is it?), Characterization (How is it?) and Valuation (Why is it? / What does it infer?). By asking these questions the different form entities are identified.

When all form entities have been identified, they are analyzed based on the four semantic functions. As these are subjective assessments, the result is heavily dependent on the experience of the members of the development team. By studying each entity systematically based on the four semantic functions, a deeper understanding of the product design features is achieved. During the analysis it should be obvious whether or not all semantic function is applicable for each form entity. It is therefore important to note that not every form entity must be analyzed based on all four functions.

**Expected result:** If the model is used on competing products, it aims to discover how the main form entities are used to achieve semantic functionality within the product category. This analysis can be done on several competing products to understand and compare in which way this is applied based on each company.

If the model on the other hand is used on the internal product family or products, the most essential form entities or design features can be interpreted, expressed and communicated within the corporation. By clearly stating the underlying purpose of each form entity and design features, the design rationale can easier be communicated interdisciplinary across the various internal divisions of the company, e.g. engineering, sales, design and marketing.

### 5.3 Syntactic Functionality Analysis

The syntactic functionality analysis is used to understand how the visually connecting or discerning structural compositions and shapes in a design affect the perception of the product. The analysis is based on the five syntactic functions described by Warell (2001) and an approach to utilize these functions, as introduced by Bergström and Söderberg (2005).

**Purpose:** By methodically examining the product and the associated design features, a deeper understanding of the design can be achieved. This understanding can be used during the product development phase to better define how syntactic functions affects the user perception of the product. The design can therefore become easier to understand and achieve a visual congruence.

**Description:** The syntactic functionality analysis describes structural composition of a product and can be used to motivate and articulate the design. There are five identified syntactic functions: Discerning, connecting, referring, uniting and balancing, as described by Warell (2001). The analysis can be done in three different ways:
1. Analyzing a single product, which defines the internal visual compositions of the design.
2. Analyzing a product family assortment, which identifies similarities and connections across the product range. This method is further elaborated in the design format analysis in section 5.4.
3. Analyzing the available products, from different companies, part of the same market segments. This is suitable as a part of the category extension strategy for a company with little prior knowledge of the market segment. This analysis can be combined with the product category analysis described in section 5.1.

Bergström and Söderberg (2005) introduces an approach to analyze syntactic functionality of a product or product family. By analyzing a single product, the inherent features of the design can be described using syntactic functions. Design features are highlighted and described. The relationships are explained connected to the syntactic functions and gestalt principles, see Figure 13.

![Figure 13: Schematic of the syntactic functionality analysis as described by Bergström & Söderberg (2005). The illustration depicts the vacuum cleaner model Pure D9 by Electrolux](image)

As the referring syntactic function is dependent on two or more models, it is not applicable for a single product. This is instead used when analyzing a product family together. In this approach the relevant products are compared side by side to identify the connecting and discerning features (Bergström & Söderberg, 2005). This approach is also relevant for determining commonalities within the product segment. This can then be used in conjunction with the product category analysis described above to even further understand how competitors utilize design to create successful products.

**Expected result:** If used internally a product-producing company may reach a greater understanding of the existing product range. The result can be used to communicate design choices in a structured way, which prevents key design features getting removed or altered during the product development process because of a lack of understanding. If used externally, better understanding of how competitors use design to create cohesive products can be achieved.
5.4 Design Format Analysis

The design format analysis compares which form element are used within a product range. It is strictly based on the method created by Warell (2001).

**Purpose:** The purpose of the design format analysis is to determine which design features and choices must or should be kept which will make new products still feel part of the same brand. It aims to answer the question of which the most essential form elements are and which can be seen throughout different product families and across generations. It is a method which analyzes the product family factors part of the design format modeling framework presented by Warell (2001).

**Description:** The design format analysis is a method which aims to find the form elements in prior existing products which are most significant to help identify them as part of the product family. This means, analyzing form elements, colors, materials etc. This is to be done on a higher product level, which implies not looking deep into each detail.

Warell (2001) uses three levels to indicate how well a certain product matches different characteristics. The three levels are represented by filled or empty circles. An empty circle means that it has a weak relation, a filled one means it has a strong relation and no circle means it is not applicable on the product at hand, as seen in Figure 14. This also includes a score range from zero to two, where a higher level of representation in the design gives a higher score. The numbers seen are the accumulative score for each row or column.

![Figure 14: An example of the results from a Design Format Analysis from Warell (2001, p. 109)](image)
If not only to gather knowledge about the existing design this analyzing method can be used early and parallel to the design process to create the new design format. This can help determine the future design direction of a product category.

**Expected result:** The expected result is a descriptive design format analysis and assessment. This enables the designers to understand how design has been conducted prior to the new product in either a product family or across products during many generations.

Through the analysis it is easier to determine either which characteristics showing most reoccurring resemblance in products or which characteristics might not be necessary to identify a product as part of a certain product family. The same goes for the analysis with a generation perspective. Then it can be determined which styling features have been used over time and which ones are the most reoccurring.

5.5 **Proportion Orientation and Shape Analysis**

The proportion orientation and shape analysis is an objective approach to understand the relationship between form elements in a product structure. It is strictly based on the method created by Ranscombe et al. (2012).

**Purpose:** The purpose of this analysis is to get a better grasp of how a specific design feature appears on a chosen set of similar products. By investigating competing products, an average for proportion can be found as well as commonly used shapes and orientation for certain features. The analysis gives an indication for how design features typically are configured. The insights can be used during the product development process to either create similarities or differences for new products.

**Description:** There are different approaches when analyzing design features and product appearance of a product or product category. One major aspect is qualitative versus quantitative models of evaluation. The qualitative approach can be considered more subjective and based on the previous experience of the designer. The quantitative approach can in turn be considered to be more objective, with analytical models based in statistics and mathematics.

Ranscombe et al. (2012) introduces an analytical framework based on the measurements of various forms and geometries entities (e.g. points, lines, spaces and areas) for the quantitative approach. The analysis is divided into three categories: *feature proportion analysis, feature orientation analysis and feature shape analysis.*

The feature proportion analysis includes length, width, perimeter and area. The principle is quite simple. A form element is measured and compared to another feature of the design to quantify the actual proportion of the form element. The proportion is calculated by dividing the measured form entity to the reference feature. (Ranscombe, et al., 2012)

The feature orientation analysis measures the relative placement of a form element to an arbitrary coordinate system. The mass center or center point of an object (depending if the object is analyzed in three dimensions or two) is measured and recorded as a coordinate in the given system ((x,y,z) in the three-dimensional space or (x,y) in the two-dimensional plane). (Ranscombe, et al., 2012)

The feature shape analysis is modeled to quantify a geometrical shape for cross-product comparison. First, the feature shapes’ centroid is determined. Then the radial length between the centroid and the exterior outline is plotted continuously throughout the curves’ length. The
amount of points needed is dependent on the complexity of the product shape and will determine the resolution of the plotted result. The radial length of each point is then plotted in the xy-plane or xyz-space, for a two-dimensional feature and three-dimensional feature respectively. (Ranscombe, et al., 2012)

The analytical framework is best suited when a fundamental similarity can be established across a variety of products, i.e. when several products display a high degree of similarity. The model can be applied viewing a specific product as a part of, or separated from, the group of products. The first approach is assessed by Ranscombe et al., (2012) as suitable for comparison within the product range of the same manufacturer, and the second approach is suitable when comparing a product to competing companies’ product ranges.

**Expected result:** The result of the proportion analysis can be in the form of a graph where the relations between certain features in different products are presented, as seen in Figure 15. There they can be compared to each other which allows for an average to be calculated.

![Figure 15: Illustration of the feature proportion analysis as depicted by Ranscombe et al. (2012, p. 501)](image)

As for the orientation analysis the measured value can be compared to other products in a similar manner using a coordinate system. The same principle is used for the shape analysis, where the plotted curve from the radial length may be compared across the selection of familiar products. This can be seen in Figure 16 and Figure 17 respectively.

![Figure 16: Illustration of the orientation analysis as depicted by Ranscombe et al. (2012, p. 501)](image)
5.6 Architecture Analysis

The architecture analysis provides an understanding of how the internal components of a product interact and is placed as a part of the design. The architecture analysis is based on the method presented by Ulrich and Eppinger (2012).

**Purpose:** The purpose of the architecture analysis is to establish the essential components for a given product. It also shows what possibilities and restrictions that emerges based on the geographical placement of said components. At the same time, it enables design choices to be made with higher certainty because of the knowledge of what the requirements of the internal structure are.

**Description:** The architecture analysis is a method for understanding the included physical and functional elements existing within a certain product. How said elements are configured within the product will affect the overall design depending on their geometrical placement.

This analysis is based on the one presented by Ulrich and Eppinger (2012) which suggests a four-step method to establish the product architecture. These are described below.

1. *Create a schematic of the product*
2. *Cluster the elements of the schematic*
3. *Create a rough geometric layout*
4. *Identify the fundamental and incidental interactions*

Firstly, the product schematic is made by listing all the functional elements as well as the physical elements, see Figure 18. The product schematic represents the collection of both the functional and physical elements and is used to increase the understanding of the constituent components of the intended design. As an example, a function could be to store energy and the physical element needed would be a battery. Between the functional elements, different types of connections should be made. This connection should be defined to establish if it is a geometric interaction or a non-contact interaction (such as data/energy transfer). Then it should be shown on the connection what is being transferred and what is used to keep the integration intact. (Ulrich & Eppinger, 2012)
Secondly, the elements should be clustered, see Figure 19. By clustering elements, the development team creates chunks. Some suitable criteria suggested by Ulrich and Eppinger (2012) to consider when clustering is:

- **Geometric integration and precision**, meaning if two elements require alignment and physical interaction, they could be suitable to cluster together
- **Function sharing**, meaning that if a physical element can incorporate two or more functional elements, they could be suitable to cluster together
- **Similarity of design or production technology**, meaning if two or more physical elements shares a design feature or production process, they could be suitable to cluster together
- **Accommodating variety**, meaning that if the product needs to be adjustable to changing customer needs, they could be suitable to cluster together

*Figure 18: Product schematic showing functional elements (bold text) and physical elements (normal text) and the connection between them*

*Figure 19: Example of the schematic after adding clusters*
In the updated schematic clusters are made to surround functions that belongs to certain physical elements. If the integration or transfer can be applied to every component inside a cluster the line may be attached to the surrounding cluster box. If there is a connection between two specific components the lines may be kept, where the line goes directly from one component to another.

Thirdly, a rough geometrical layout is to be created, see Figure 20. The geometric layout can be created through a rough estimation of the physical element size and geometry. Preferably, the geometric layout should be created as a three-dimensional model where the chunks are placed at their estimated position in relation to the other chunks. Their size and geometry should be kept close to how it will be in reality. This can be used as a feasibility test to see if their layout would work in practice. (Ulrich & Eppinger, 2012) Thus, this may be seen as a method to test if the clustered chunks have been properly assigned, and leaves room for alteration of the grouping.

Lastly, the fundamental and incidental interactions should be identified. Fundamental and incidental interactions appear when all the physical elements and chunks are assembled and functioning together. The fundamental interactions are intended and already identifiable by looking at the lines in the schematic. The incidental interactions emerge because of the geometrical arrangement and physical interaction and must be documented in another way. Depending on the number of interacting chunks there are two different methods to document these. For up to around a total of ten chunk interactions Ulrich and Eppinger (2012) suggest an interaction graph. For more complex systems the same authors recommend an interaction matrix instead. (Ulrich & Eppinger, 2012)

As this thesis does not consider mechanical structure or calculations of the developed concept, the fundamental and incidental interactions are not further elaborated or considered in the case application.

**Expected result:** The outcome from doing an architecture analysis is the four elements described above: A product schematic, component clusters, a geometric layout and fundamental and incidental interactions. By creating these four elements, an understanding of
what physical and functional elements exists and their connections (geometric interaction or a non-contact interaction). Chunks are defined, which also describes the relationship between the major building blocks of the design. The geometrical layout identifies in which way various components can be placed, based on the physical layout, and the interaction between physical elements is defined. The method is expected to provide key insights into the product architecture, which will fundamentally affect the product basic form and ultimately the entire exterior design.
6 Design Guideline Framework

What design guidelines are, how to develop them and how to use them is not strictly defined in the investigated literature. For a product-producing company, it is the design features that are the central aspects of the design guidelines. Design features are, as previously defined, the building blocks in a product that designers utilize to create a coherence and recognition within product portfolio (Andersson, 2016; Hollins & Pugh, 1990; Lewalski, 1988; Warell, 2006; Karjalainen & Snelders, 2010; Ranscombe, et al., 2012; Person, et al., 2007). By creating design guidelines and implementing them on a product range, this coherence can be achieved. It is through the repetitive use of design features over time that generates the recognition on the market. This is what eventually will become part of the brand and design DNA, as these unique characteristics become closely related to the company (Andersson, 2016; Person & Snelders, 2009). It is not only the purely physical design elements that are of importance for a product design. It is also the intangible product properties which are interpreted by the perceiver that affect the experience.

In order to better understand which design features to incorporate and how to structure them, an examination of what could be found within the literature is conducted. A total of 10 different articles, publications and books are included in the investigation. By investigating what features are introduced, mentioned or defined in this literature, an estimation of which design features to incorporate can be concluded. In some of the included articles these features are structured into categories, which is also taken into consideration. The result is collected in a table, where the features are presented, sometimes grouped under a category name, connected to each article, publication or book. This table can be found in Appendix A. This information is then translated into a collected list of design features which is then grouped and described. The foundation of the framework is based on the division of explicit and implicit features, as introduced by Andersson (2016).

6.1 Explicit Features

The explicit features are defined as the tangible features that enable the design to facilitate a visual recognition towards a brand (Andersson, 2016). These features also connect the product to the market segment in which competing products share specific properties. This visual recognition is related to the current product sign within the product segment (Monö, 1997). On a competitive market the explicit features imply a differentiation of the product offer. The identified explicit features are categorized accordingly:

- **Main form**: The main forms of a product, the fundamental building blocks (Österlin, 2011)
- **Dominating form**: The main lines, shapes and forms which are visible on a product and are related to product character (Österlin, 2011)
- **Details**: The design elements which become apparent after closer inspection of the product (Österlin, 2011)
- **Structure**: The actual configuration and reoccurrence of different design elements on a product
- **Color, material and finish**: The colors, material and finish are the design features normally seen on the surface of a product
- **Graphics**: The elements which are the visual representations connected to the brand

The identified explicit design features are presented and illustrated in Table 3.
Table 3: Identified explicit design features

<table>
<thead>
<tr>
<th>Point</th>
<th>Even something as simple as a point can be used to indicate dynamics in relation to its’ surroundings. Even if not visually present, other details may converge towards a certain point which may be used in a design.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>A line can be straight, sharp angled or softly curved. There are many ways to use lines in a design to create details which makes one design different from others, even if just ever so slightly.</td>
</tr>
<tr>
<td>Surface</td>
<td>Products typically consist of many different surfaces. These can be flat, curved, double-curved or deformed in many other ways.</td>
</tr>
<tr>
<td>Curvature</td>
<td>Curvatures may be added to surfaces to create a more dynamic look. By utilizing curvatures, it is possible to distinguish certain surfaces from others and changes the overall look of the entire product.</td>
</tr>
<tr>
<td>Shape</td>
<td>The shape of a product is the 2D imagery which can be perceived. Every product, if deconstructed, consists of basic shapes such as squares, triangles and circles.</td>
</tr>
<tr>
<td><strong>Silhouette</strong></td>
<td>![Image]</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>The geometric silhouette of a product is the outline of said object. A unique silhouette can be created utilized by a company to help customers recognize their products more easily.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Form</strong></th>
<th>![Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td>The form of a product is the basic 3D imagery which can be perceived. In this case it would be, rather than the 2D shapes, a cube, tetrahedral or sphere. Forms should not be made as a coincidence, rather they should be related to specific, underlying properties of the design.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Proportion</strong></th>
<th>![Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be described as the spatial relationship between two form elements in a visual composition by measuring the ratio of the constituent elements. By correct usage of proportion, certain design elements might appear as more important than others thanks to their difference in size.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Scale</strong></th>
<th>![Image]</th>
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</thead>
<tbody>
<tr>
<td>The scale of a product can only be seen when it is put into context of another object. By understanding the effect of proportion and scale, it can then be determined whether the scale of the product should be increased or decreased to achieve the best possible outcome.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Angles</strong></th>
<th>![Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angles are defined as two lines which are diverging from a common point. Angles can be used to create chamfers around edges or to enable more shapes to take place in the design.</td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Design elements can be placed in different positions in relation to each other. This can be utilized to make smart design decisions by carefully thinking about the layout of the included elements.</td>
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<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Orientation</strong></td>
<td>The orientation, or angular position, implies the relative rotation of a form element in relation to co-existing elements.</td>
</tr>
<tr>
<td><strong>Symmetry</strong></td>
<td>A symmetric object is made of two mirrored parts facing each other around a central axis. Forms in design may be symmetric, or in contrast, asymmetric, which will affect the interpretation of the product.</td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td>Can be described as multiple lines or features which are not physically connected but feels connected because the relative configuration.</td>
</tr>
<tr>
<td><strong>Alignment</strong></td>
<td>By aligning two design features they become connected which provides structure to the design. Aligned features can be connected in the interface between components.</td>
</tr>
</tbody>
</table>
**Rhythm**
This includes reusing design features repeatedly in a certain configuration. Such as chunks of elements appearing after one another. Another type of rhythm is a slide reflection, where a pattern is mirrored over an axis.

**Distributed vs. Enclosed**
Because of the nature of distributed and enclosed form elements, as described by Warell (2001), they cannot co-exist in the same physical product form. The former implies design features crossing the main structure outline and the latter means all design features stay inside the structure.

**Discrete vs. Composed**
Discrete and composed form elements are not able to co-exist, as described by Warell (2001). The former implies a form realized by a single element and the latter means a form realized by a grouping of elements.

**Signature Feature**
These are features which are aimed to be frequently applied (or adapted) to the product range which creates a more consistent and recognizable look and feel throughout the product portfolio.

**Color**
Utilizing colors on a products surface enables it to send different signals to the perceiver depending on which color is used. It can also help giving the surface a better finish by hiding imperfections in the pure material. Therefore, correct color usage can be very impactful for the overall design.
### Material
Different materials have different properties such as texture, temperature, density and mechanical strength. All these factors matter for the overall outcome of a product, not only for the appearance and feel, but also for the cost of producing the product and the product durability.

### Texture
The texture on the surface of a product can have both a visual and functional meaning. For instance, it can look aesthetically pleasing with a certain texture while the feel of it might also give an indication for where to interact with the object. Certain textures can be more grip-friendly than others or softer to indicate a safer feel.

### Reflectiveness
Reflectiveness is included in the surface finishing and can be used to create a more exclusive look. At other times however, reflective areas should instead be avoided, depending on the design.

### Transparency
Transparent surfaces could be advantageous if it is desired to show the contents sealed behind. Such as for light sources, a semi-transparent material will allow the light to pass through and also help with the spreading of light.

### Logotype
A logotype can help with the recognizability of the product by putting the logotype where it is clearly visible to the consumers.
Based on the findings in literature the design features are grouped according to the categorization of main form, dominating forms, details, structure, color, material and finish and graphics. This is presented in Table 4.

**Table 4: Grouped explicit design features according to the identified categories**

<table>
<thead>
<tr>
<th>Main Form</th>
<th>Dominating form</th>
<th>Details</th>
<th>Structure</th>
<th>Color, material and finish</th>
<th>Graphics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Surface</td>
<td>Point</td>
<td>Symmetry</td>
<td>Color</td>
<td>Logotype</td>
</tr>
<tr>
<td>Silhouette</td>
<td>Orientation</td>
<td>Line</td>
<td>Orientation</td>
<td>Material</td>
<td>Graphical elements</td>
</tr>
<tr>
<td>Form</td>
<td>Curvature</td>
<td>Curvature</td>
<td>Alignment</td>
<td>Texture</td>
<td></td>
</tr>
<tr>
<td>Proportion</td>
<td>Continuity</td>
<td>Location</td>
<td>Rhythm</td>
<td>Reflectiveness</td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td>Angles</td>
<td>Orientation</td>
<td>Distributed-Enclosed</td>
<td>Transparency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Signature feature</td>
<td></td>
<td>Discrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Composed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2 Implicit Features

Implicit design features are intangible and related to the overall feeling of the product connected to the emotional response of the perceiver (Andersson, 2016). These intangible features are connected to semantic and syntactic functionality part of the physical design. The chosen materials for the product can also possess these qualities, described as the intangible characteristics of materials (Karana, et al., 2007). Implicit design features can even include aspects as abstract as the perceiver’s interpretation of the brand identity.
The identified implicit features are categorized accordingly:

- **Brand identity**: The conjunction between the key beliefs and values of a brand. With the addition of visual style and form language it creates the visual brand identity of a brand

- **Product expression**: The communicative properties of a design connected to semantic functionality

- **Syntactic functions**: Syntactic functions can be described as the visually connecting or discerning structural compositions and shapes in a design

- **Contrast and balance**: The perceptual difference and harmony between two or more form elements part of the same design

6.2.1 Brand Identity

Brand Identity is defined as the conjunction between the key beliefs of a brand and its core values (Kapferer, 2008). The brand identity category includes four implicit design features: Brand values, Design philosophy, design DNA and Differentiation. These are described below.

**Brand values**

Part of what defines a brand is its values. Whenever a potential customer sees a product from a specific brand any prior association will come to mind as there is a connection between a product design and the brand values (Andersson, 2016). One way to steer these thoughts in the desired direction can be to utilize value words when working with the design process. It is important to consider what associations the brand wants to convey to its consumers and implement it through clever design choices, as this influences the recognition of a new product. (Kreuzbauer & Malter, 2007)

**Design philosophy**

Having a well-established design philosophy which can be seen across all the products under the same brand can make it easier to succeed on markets with a high number of competitors (Karjalainen & Snelders, 2010; Österlin, 2011). For instance, it might be important to be known as very reliable in the sense that the products last for long periods of time, or that the expert service is included with each purchased product.

**Design DNA**

Utilizing design DNA means re-using features from previous products (Andersson, 2016). By creating these connections, it is easier for the consumers to see the new products as part of the same brand. Then, previous positive associations will be linked to the new line-up as well.

**Differentiation**

One of the key factors to standing out in the market is to be different from the competitors. Creating a design which stands out among the vast number of products will increase the likelihood to be recognized if used consistently (Warell, 2015). However, one prerequisite is that the brand already is tied to positivity among the users. Otherwise it might have the opposite effect which means the products are avoided instead. (Kreuzbauer & Malter, 2007)

6.2.2 Product Expression

The product expression category includes five implicit design features: Character, Identity, Function, Intention and Exhortation. These are described below.
Character
The product character communicates a quality, property, expression and emotional association of a product. People tend to associate certain forms and features to certain properties. A product character communicates this property of a product, e.g. heavy, light, compact and dispersed. It can also display emotional properties, e.g. happy, angry, friendly and hostile. (Österlin, 2011)
By deciding what character expression is desirable for the product you can better understand and motivate what features should be incorporated into the design.

Identity
The product identity is a property that communicates the product origin, heritage, purpose, affiliation, placing and category (Monö, 1997). By consciously and carefully choosing cohesive identity carriers, a heritage and context can be conveyed to the user (Österlin, 2011).
An identifying property could as an example include logotypes, product names, colors, or icons. Consistent use of design features generates a powerful and united brand image which differentiates the company from its competitors (Österlin, 2011).

Function
A product can, through the design, communicate the intended functionality (Monö, 1997). The functionality of a product can always be specified in a data sheet or an instruction manual, but if no effort is placed on the communicative aspects of the design the product will still be difficult to understand. A well-designed product form can convey the intended functionality without words, symbols or manuals. This fundamental principle will drastically increase the usability of the product, and hopefully the user satisfaction.

Intention
Product intention is a property and communicates to the user through various channels. A design that conveys intention is key for product understanding. Sometimes it is enough to incorporate a small detail which communicates the intention to a user. Other times it is better to design a feature that boldly deviates from the rest of the product, to gain the user’s attention. (Österlin, 2011) This is what the developing team must take into consideration during the product development.

Exhortation
A product exhortation is a property of the design that provokes or invites a reaction from the user (Monö, 1997). The product form or gestalt is a key factor for product understanding, and by creating a coherence to user expectations, frame of reference and needs, the exhorting properties can be easily recognized by the user (Österlin, 2011).

6.2.3 Syntactic Functionality
The syntactic functions are defined as the visually connecting or discerning structural compositions and shapes in a design (Warell, 2001) The syntactic functionality includes five implicit design features: Discerning, Connecting, Referring, Uniting and Balancing. These are described below.

Discerning
The discerning syntactic function separates two form entities from each other by creating them with identifiable and apparent differences, such as color, material, shape and form (Warell, 2001).
Connecting
The connecting syntactic function creates a partial visual coupling between the form entities by purposefully letting them share some specific properties. This could imply simple design features such as a reoccurring curves or shapes within the design. As these features display a relationship, even though they are separated in the visual space, it connects the design. Connecting syntactic functions can thus be used to create a cohesive and qualitative design language. (Warell, 2001)

Referring
Referring syntactic functions creates a connection between two different products by a visual relationship of specific form elements. The referring syntactic function can be used to create a visual connection between the products of a product range (Warell, 2001). Through consistent use of referring functions these design features will transform into a part of the design DNA of the company (Andersson, 2016).

Uniting
Uniting syntactic functions connects two form entities within the same product by sharing a common gestalt. This functionality can be used to create a visual congruence and balance within the design. (Warell, 2001)

Balancing
Balancing syntactic functions create a visual harmony in the design by visual counteraction such as the use of symmetry, contrast and rhythm (Warell, 2001). This type of functionality is further elaborated in the contrast and balance category.

6.2.4 Contrast and Balance
Contrast and balance are defined as the perceptual difference between two form elements and the unresolved tension and relationship between two form elements, respectively (Stebbing, 2004). The contrast and balance category include 6 implicit design features: Location, Isolation, Orientation, Symmetry, Weight and Intrinsic interest. These are described below.

Location
In terms of implicit features, the location of said features can create a balance or imbalance in the design. Therefore, the placement of the features needs to be thought of to make sure there is a visual harmony in design.

Isolation
Isolating certain features from the rest can also create balance or contrast in the overall design. If the design seems to be lacking in these aspects, try placing features far away from the rest.

Orientation
By purposefully creating different orientations of form elements it generates a contrast in the visual perception of the product gestalt.

Symmetry
To create balance in the design, symmetry can be used. By mirroring form elements over an axis, they create a connection within the design.
Weight
Weight does not imply the actual mass of a feature but instead the perceived weight. Different colors with high or low color intensity can be interpreted as having higher or lower weight. Using the same amount of red and blue could still lead to one being ‘heavier’. The same principle is applicable for shapes: Complex shapes could be perceived as heavier than simple ones for instance. The perceived weight of form elements can both create balance or contrast, depending on the configuration. (Stebbing, 2004)

Intrinsic interest
A feature having intrinsic interest (or value) means it is interesting by nature and not because of prior connections with it. By creating certain form elements with high intrinsic value in contrast to other elements with low value, a balance can be achieved. Thus, it is important to know which features have this quality during the design process.

The implicit design features described in this chapter is summarized in Table 5.

Table 5: Implicit design features

<table>
<thead>
<tr>
<th>Brand identity</th>
<th>Product expression</th>
<th>Syntactic functionality</th>
<th>Contrast and balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand values</td>
<td>Character</td>
<td>Discerning</td>
<td>Location</td>
</tr>
<tr>
<td>Design philosophy</td>
<td>Identity</td>
<td>Connecting</td>
<td>Isolation</td>
</tr>
<tr>
<td>Design DNA</td>
<td>Function</td>
<td>Referring</td>
<td>Orientation</td>
</tr>
<tr>
<td>Differentiation</td>
<td>Intention</td>
<td>Uniting</td>
<td>Symmetry</td>
</tr>
<tr>
<td></td>
<td>Exhortation</td>
<td>Balancing</td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intrinsic interest</td>
</tr>
</tbody>
</table>
7 Literature Review Summary

In this chapter the results from the literature review are summarized, including the theoretical framework, form analysis framework and design guideline framework.

In this thesis the branded house strategy is considered, meaning the product range should exhibit a unified visual recognition part of the visual brand identity. The brand identity is also connected to the history of the company and the unique characteristics that are developed over time, defined as the design DNA. As a part of a category extension strategy, all these aspects need to be taken into consideration when moving into a new product category.

Firstly, a successful product design is dependent on several, equally important, variables. The product needs to communicate a heritage, through the visual style part of the brand identity. It should also exhibit a connection to the market segment and product category. At the basic level, the product needs to be sufficiently similar to competing products. Likewise, the design features need to display a clear differentiation compared to competitors and positive associations towards the brand, which is defined as the sub-ordinate level of the design and the point of difference. Finally, the product design must be understandable and aesthetically pleasing, by considering the product gestalt, semantics, syntactics, visual composition and material properties.

Design syntactics is a framework defined by Warell (2001) for three conceptual elements: form functionality, form syntactics and design format. It is used to define the structure, functioning of form, composition and content of a visual form design, which can be part of the internal, external or product family factors. This framework is the basis for the form analysis framework defined in this thesis.

From the literature review, a total of six different methods are identified as applicable for analyzing product design part of the form analysis framework. The methods are used to analyze different aspects of product design. This ranges from gathering knowledge about general shape and form to product portfolio design features. Because of their differences they work best if used in combination complementary to each other. This provides a holistic understanding of the chosen product segment or physical design. The methods, their field of study and area of application is presented in Table 6.

The purpose of the form analysis frameworks is to cover the most important and essential aspects of product design understanding. The aim is that the various methods can be used to understand the internal and external factors as well as the product family of a company related to product design. It can be used to analyze, define and communicate form elements and design features of existing products within the product category.

Design guidelines is a term that is not found to be strictly defined in literature and is often interpreted differently depending on which company that utilizes them. By summarizing all the theoretical models and existing frameworks within the area a design guideline framework has been developed. The framework is divided into explicit and implicit design features, with the purpose to cover both the tangible and intangible aspects of product design. Design features are the constituent elements of the design guidelines, defined as the building blocks that can be used to generate a coherency within a product portfolio. The complete design guideline framework is presented in Figure 21.
Table 6: The six different form analysis methods presented in chapter 5. Their corresponding field of study and area of application as introduced by Warell (2001)

<table>
<thead>
<tr>
<th>Analytical method</th>
<th>Field of study</th>
<th>Area of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product category analysis</td>
<td>General shape and form</td>
<td>External</td>
</tr>
<tr>
<td>Semantic functionality analysis</td>
<td>Product expression</td>
<td>Internal/External/Product family</td>
</tr>
<tr>
<td>Syntactic functionality analysis</td>
<td>Visual relationship between design features or form elements</td>
<td>Product family / External</td>
</tr>
<tr>
<td>Design format analysis</td>
<td>Product portfolio design features</td>
<td>Product family</td>
</tr>
<tr>
<td>Proportion orientation and shape analysis</td>
<td>Quantitative comparison for product category</td>
<td>External</td>
</tr>
<tr>
<td>Architecture analysis</td>
<td>Product structure and component interaction</td>
<td>External</td>
</tr>
</tbody>
</table>

It can be concluded that the term design guidelines need to be explored further. This thesis is a step in that direction. As the term guideline suggest, it is not supposed to be considered as strict rules. Any alteration required to better fit each individual company may be made when necessary. They are general enough to be applied to any product-producing company interested in creating a coherent design throughout their product portfolios.
### Explicit features

<table>
<thead>
<tr>
<th><strong>Main form</strong></th>
<th><strong>Dominating form</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The main forms of a product, the fundamental building blocks</td>
<td>The main lines, shapes and forms which are visible on a product and are related to product character</td>
</tr>
<tr>
<td>Shape, Silhouette, Form, Proportion, Scale</td>
<td>Surface, Orientation, Curvature, Continuity, Angles, Signature feature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Details</strong></th>
<th><strong>Structure</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The design elements which become apparent after closer inspection of the product</td>
<td>The actual configuration and recurrence of different design elements on a product</td>
</tr>
<tr>
<td>Point, Line, Curvature, Location, Orientation</td>
<td>Symmetry, Orientation, Alignment, Rhythm, Distributed - Enclosed, Discrete - Composed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Color, material and finish</strong></th>
<th><strong>Graphics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The colors, material and finish are the design features normally seen on the surface of a product</td>
<td>The elements which are the visual representations connected to the brand</td>
</tr>
<tr>
<td>Color, Material, Texture, Reflectiveness, Transparency</td>
<td>Logotype, Graphical element, Symbols</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Implicit features</strong></th>
<th><strong>Brand identity</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The conjunction between the key beliefs and values of a brand. With the addition of visual style and form language it creates the visual brand identity of a brand</td>
<td>Brand values, Design philosophy, Design DNA, Differentiation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Product expression</strong></th>
<th><strong>Syntactic functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The communicative properties of a design connected to semantic functionality</td>
<td>Syntactic functions can be described as the visually connecting or discerning structural compositions and shapes in a design</td>
</tr>
<tr>
<td>Character, Identity, Function, Interaction</td>
<td>Discerning, Connecting, Referring, Linking, Balancing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Contrast and balance</strong></th>
<th><strong>Location</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The perceptual difference and harmony between two or more form elements part of the same design</td>
<td>Location, Isolation, Orientation, Symmetry, Weight, Intrinsically</td>
</tr>
</tbody>
</table>

*Figure 21: The Design Guideline Framework showcasing the explicit and implicit features*
8 Case: Autonomous Mobile Robot

Robots have been part of the manufacturing industry for a long time and something that is gaining more attention as of late are autonomous mobile robots, see Figure 22. These robots can for instance be used to transport goods between production and warehouse or in the medical department to autonomously transport medicine long distances which humans would otherwise need to do (MIR, 2017).

There are two main categories of industrial mobile robots: Automated Guided Vehicles (AGV) and Autonomous Mobile Robots (AMR). The main difference is that the AGVs only follows fixed routes and need a guide structure installed in the target location to be able to navigate. This guiding structure is often magnet strips or wires installed in the floor. The AMRs on the other hand utilizes numerous sensors which scans the surrounding. This information is processed by an on-board computer and compared to installed maps of the environment. This way these robots can choose the optimal route and avoid objects and people on its way to the destination. The main benefit of AMRs is the adaptability, as these robots can adjust their trajectory to changes in its surroundings. (Fetch Robotics, 2019)

This thesis is done in collaboration with a company which is a supplier of industrial robot solutions. This company will not be mentioned by name in this thesis and is called the case company, or the company for short. The case company has analyzed future markets based on current trends in industry automation and new possibilities of mobile robots. The company aims to develop a new product line of autonomous mobile robots to meet future customer needs. These robots will be modular and therefore adjustable to different markets and user needs.

This thesis includes a product development process of autonomous mobile robots for the case company. The process includes activities such as ideation, workshops and concept creation. The developed concept is made to be modular and adjustable for various customer needs. This implies modularity with regards to product scale, shape and included components. The design process is based on the form analysis framework, defined in chapter 5. Through this framework a better understanding of the product category and design is achieved. Design guidelines are developed for the case company based on the chosen concept and the design guideline.
framework, presented in chapter 6. These guidelines will also be created with the AMR product category in mind. The case company also has a set of outdated design guidelines today and wish to expand these guidelines for this new product category. These existing guidelines will also be taken into consideration during the product development process and the design guideline development.

This chapter first introduces the application of the form analysis framework, followed by the product development process and final concept of the modular AMR concept for the case company. Finally, the design guideline development relevant to the case is presented.

8.1 Case: Form Analysis

The form analysis relevant to the case includes a product category analysis, semantic functionality analysis, syntactic functionality analysis, design format analysis and architecture analysis. The purpose of these is to better understand the product category of autonomous mobile robots regarding product design, expression, semantics and syntactics in the industrial context of the case company.

8.1.1 Product Category Analysis

The product category analysis is used to understand the product category of mobile robotics. The aim is to see what design features and functions that are reoccurring in competing products, which gives an indication to what is necessary to incorporate in the new product line. The basic and differentiating levels are investigated, as described in section 5.1. First a total of 29 different models of mobile robot platforms from 17 different companies are included in the analysis. These platforms are either AMRs or AGVs. Examples of companies that is included in the analysis are Evo Oppent, DoraBot and KUKA, see Figure 23.

Through the visualizations and information from the competitors’ websites, different areas of application are established. These include: Top-loaded small batch transfer, Secured small batch transfer, Lift-based systems, Heavy-duty transfer, Pull-based systems and Mobile manipulation, see Figure 24. The mobile platforms can stay within one of these areas or expand over multiple at the same time. There are even cases when they are able to transform from one to another by attaching modules somewhere on the structure.

![Figure 23: Robot models from competing companies. From left: Evo Oppent cobot, Dorabot MOMA and KUKA Omnimove.](image)
The most common areas are top-loaded small batch transfer and lift-based systems, see Figure 25. This is taken into consideration in future design choices and concept generation. Either it can be beneficial to focus on the areas where the market is already diverse since the demand is most likely higher. The other direction would be to focus on areas where most competitors have yet to offer any solutions. Because of the modularity aspect, which is a high priority for this thesis, a mix between different areas of application will be relevant.

Figure 24: The identified application areas. From left to right: Top-loaded small batch transfer, secured small batch transfer, lift-based systems, heavy-duty transfer, pull-based systems and mobile manipulation

Figure 25: A collection of the identified areas of application for various competitors' mobile robots.
On the basic level the general features of the product category are analyzed, independent of which company is the producer. In this analysis the overall design features are examined, such as shapes, surfaces, lines, proportion, and symmetry. General design principles are also analyzed. The result is presented in Figure 26. As there are fundamental differences between various models, meaning the proportion, scale and silhouette, the gist analysis of the product category is left out in this case.

Through the analysis it is concluded that there is a significant difference between AGVs and AMRs. The AGVs are longer and have a lower profile while the AMRs feature a less rectangular base and a higher profile. There are also several similarities. Horizontal design features such as lines and surfaces (instead of vertical) are reoccurring. The design is often sectioned in a bottom and top, with a horizontal cutout along the sides. It also seems to be a common practice to use symmetry and proportion to communicate the intended direction. Asymmetrical design features are considered to indicate a primary direction, which is interpreted as a front of the design. The opposite (symmetrical structure along the horizontal axes) communicates an omnidirectionality. By using a long base compared to the sides a sense of direction is also accomplished.

On the differentiating level the analysis is based on the differentiating features of each company. Here the products’ explicit features are examined, including design features from categories in the design guideline framework: main form (e.g. shape, silhouette, proportion), dominating form (e.g. orientation, curvature, surfaces), details (e.g. lines, location), structure (e.g. symmetry, alignment, orientation) color, material and finish (e.g. texture, reflectiveness, transparency) and graphics (e.g. logotypes and symbols). The product category analysis is also combined with the proportion orientation and shape analysis presented in section 5.5. In this case application only the proportionality is analyzed. The entire differentiating level analysis is presented in Appendix B.

*Figure 26: Basic level style analysis.*
This study shows a clear standard for how these robot platforms generally are designed, depending on their application area. The silhouette and shape of each product is recreated for each model compared to a rough estimation of the scale and proportionality of the product and its design features. The proportion is calculated by dividing a measured form element to a reference feature. In this case the width and height are the corresponding form elements, and the length is the reference feature, see Figure 27.

The proportion orientation and shape analysis described in section 5.5 is best suited when a fundamental similarity can be established across a variety of products, i.e. when several products display a high degree of similarity. The fundamental similarity is defined by Ranscombe et al., (2012, p. 506) as “…the presence of comparable features and observable similarity to the point where distinctiveness between products is based on nuances in feature shape, relative position and proportions between features”.

As this fundamental similarity generally cannot be considered to exist for the wide range of AGVs and AMRs, the quantitative approach is not automatically applicable. That said, the feature proportion analysis is considered suitable for the comparison between the base dimensions of various models. By separating the AGV-robots from the AMR-robots, the differences between the two categories is distinguished and analyzed. The length, width and height of 7 AGVs and 8 AMRs are compared in Table 7. The values of the width and height is then divided by the length of each product, calculating the relative proportion.

From the analysis two major conclusions can be drawn. Both the AGV and the AMR are displaying properties of a cuboid. Only one of the compared models (Robotnik RB-1 Base) has a symmetrical circular shape. The second conclusion is that the AMRs tend to be proportionally taller and wider, which converges towards a cubical shape. This is particularly obvious when comparing the average proportion between the width/length and the height/length. Here the average AGV width corresponds to roughly 1/2 of the length and the height corresponds to roughly 1/4 of the length. Similarly, the average width of the AMR is roughly 3/4 of the length and the height roughly 1/2 of the length.
Further, from the differentiating level analysis additional insights are generated. Some reoccurring form features are flat top surfaces which allows objects to be placed on top of the AGV/AMR and then transferred to another location. A flat top surface also acts as an area where additional modifications may be utilized to change the area of application when desired. Many of the competing products also feature rounded corners and straight vertical sides. Another common feature is cut-outs which allows for placement of sensors which are essential for the platforms to navigate. LED strips are in many cases also present to indicate direction of movement and to make the robots more noticeable during operation. An example of the analysis is presented in Figure 28.

To better understand the usage of colors on the market the color distribution of the included products is analyzed. The insights from this type of analysis can be used by a company to differentiate itself by choosing specific color combination that is not common on the market. Similarly, color can be used within a product category which is one of the factors that defines the category. In order to belong within the category, the same color scheme should be used by most or all actors, especially if the color is connected to the current product sign. Color can also be used as identity carriers, creating recognition towards a brand.

<table>
<thead>
<tr>
<th>AGV</th>
<th>Model</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Width/Length</th>
<th>Height/Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swisslog Kuka</td>
<td>TransCar</td>
<td>1706</td>
<td>580</td>
<td>330</td>
<td>34,0</td>
<td>19,3</td>
</tr>
<tr>
<td>Vecna Robotnik</td>
<td>KMP 1500</td>
<td>2000</td>
<td>800</td>
<td>470</td>
<td>40,0</td>
<td>23,5</td>
</tr>
<tr>
<td></td>
<td>Conveyer</td>
<td>1171</td>
<td>568</td>
<td>341</td>
<td>48,5</td>
<td>29,1</td>
</tr>
<tr>
<td></td>
<td>AGVS</td>
<td>1750</td>
<td>652</td>
<td>345</td>
<td>37,3</td>
<td>19,7</td>
</tr>
<tr>
<td></td>
<td>P1000</td>
<td>1300</td>
<td>940</td>
<td>340</td>
<td>72,3</td>
<td>26,2</td>
</tr>
<tr>
<td></td>
<td>P500</td>
<td>920</td>
<td>690</td>
<td>280</td>
<td>75,0</td>
<td>30,4</td>
</tr>
<tr>
<td></td>
<td>M100</td>
<td>740</td>
<td>500</td>
<td>210</td>
<td>67,6</td>
<td>28,4</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>1370</td>
<td>676</td>
<td>331</td>
<td>53,5</td>
<td>25,2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AMR</th>
<th>Model</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Width/Length</th>
<th>Height/Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIR</td>
<td>100</td>
<td>890</td>
<td>580</td>
<td>352</td>
<td>65,2</td>
<td>39,6</td>
</tr>
<tr>
<td>Omron</td>
<td>LD</td>
<td>699</td>
<td>500</td>
<td>383</td>
<td>71,5</td>
<td>54,8</td>
</tr>
<tr>
<td>Fetch</td>
<td>Freight</td>
<td>559</td>
<td>508</td>
<td>359</td>
<td>90,9</td>
<td>64,2</td>
</tr>
<tr>
<td>Clearpath</td>
<td>Ridgeback</td>
<td>932</td>
<td>793</td>
<td>298</td>
<td>85,1</td>
<td>32,0</td>
</tr>
<tr>
<td></td>
<td>OTTO 100</td>
<td>750</td>
<td>550</td>
<td>304</td>
<td>73,3</td>
<td>40,5</td>
</tr>
<tr>
<td>Milvus</td>
<td>Seit 100</td>
<td>890</td>
<td>650</td>
<td>297</td>
<td>73,0</td>
<td>33,4</td>
</tr>
<tr>
<td>Robotnik</td>
<td>RB-1 Base</td>
<td>500</td>
<td>500</td>
<td>251</td>
<td>100,0</td>
<td>50,2</td>
</tr>
<tr>
<td></td>
<td>RB-2 Base</td>
<td>990</td>
<td>633</td>
<td>450</td>
<td>63,9</td>
<td>45,5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>776</td>
<td>589</td>
<td>337</td>
<td>77,9</td>
<td>45,0</td>
</tr>
</tbody>
</table>
8.1.2 Semantic Functionality Analysis

A semantic functionality analysis is done on one of the case company industrial robots with the aim to identify product functions, characteristics, identity and exhorting properties. This knowledge provides insights of how the company utilizes design today for semantic functionality. The result is then used to translate similar semantic properties into the new design. The analyzed robot is quite different from the rest of the product range of the case company. It can even be stated that a majority of the design features are completely redesigned compared to the rest of the company’s products. The company expresses the desire to take this robot into consideration during the product development phase, as it is believed that the design language of the robot will be translated in the future into new products as well.

The semantic functions cannot be illustrated on pictures of the analyzed robot, as it will disclose the company identity. Some sections from the semantic functionality analysis is also removed from the full version due to the confidentiality agreement with the company. Nevertheless, the analysis can still show how the method is applied and adapted to the case.

The robot is designed with a lower metal base that is spray-painted with a bright color. The top of the robot body is enclosed with plastic cover in the same bright color as the base. The arms of the robot are made of a softer material with a darker hue. The soft material of the arms is separated by hard plastic covers in the joints of the arms. The analysis is done on five main form entities of the robot design: The entire product, lower metal base, top plastic covers, soft robot arms and hard plastic arm components. The sectioning of the design is based on these features, which are sufficiently different which makes the form entity easy to identify. The analysis is slightly altered from the basic description in section 5.2, by adding relevant subsections to each main form entity. Some specific design features (here named aesthetic indent and circular joint) are also analyzed, see Figure 29. The semantic functionality analysis is presented in Table 8.
By analyzing the identified form entities according to the semantic functions, several insights of the product design are found. The analysis shows that using spray-painted metal components in lighter colors is connected to a more professional and qualitative style. It is also perceived as sturdy and durable. This contrasts with the plastic covers in the same color that does not express the same quality or sturdiness. The plastic also seems to attract dirt from its surroundings, where the metal components does not.

Further, it is clear that the company persistently uses color and material to communicate the intended functionality of the products. The soft, darker material is interpreted as approachable and interactable, while the separating white plastic material indicates a non-interactive and neutral surface. It is also interpreted that the rounded, softer shapes indicate an approachable product. The wider base of the robot also shows that the product is stationary and immovable.
Table 8: Semantic functionality analysis of one of the company’s robots

<table>
<thead>
<tr>
<th>Company robot</th>
<th>Describing semantic function</th>
<th>Expressive semantic function</th>
<th>Exhorting semantic function</th>
<th>Identifying semantic function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top level – entire product</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Product gestalt</strong></td>
<td>The wide bottom base indicates a stationary design. The arms indicate product application flexibility.</td>
<td>The silhouette communicates a complexity, flexibility and also a fragility. The curvature of the back-hand side signals submissiveness.</td>
<td>The arm positioning and the body form exhorts the user to manipulate the arm.</td>
<td>Coherence in color palette and logotype with the company product range.</td>
</tr>
<tr>
<td><strong>Lower metal base</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Stationary design</td>
<td>Solid, sturdy</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Top plastic covers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td></td>
<td>Cheap, brittle, flimsy</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Indicates that the robot is not designed for dirty processes.</td>
<td>Clean, light</td>
<td>Identity carrier for the company product range.</td>
<td></td>
</tr>
<tr>
<td><strong>Robot arms – Soft material</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Communicates that the product is interactable</td>
<td>Soft, approachable</td>
<td>Invite user interaction</td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Diversify the functional surfaces from non-functional</td>
<td>Formal, industrial, modern</td>
<td>Identity carrier for the company product range</td>
<td></td>
</tr>
<tr>
<td><strong>Smooth surfaces</strong></td>
<td>Indicate that the robot is safe to interact with</td>
<td>Simple, safe</td>
<td>Invite user interaction</td>
<td></td>
</tr>
<tr>
<td><strong>Form - Aesthetic indent</strong></td>
<td>Indicate a reoccurring functional surface</td>
<td>Interactive, structured</td>
<td>Invite the placement of user hands</td>
<td></td>
</tr>
<tr>
<td><strong>Form – Circular joint</strong></td>
<td>Indicating axis placement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Robot arms – Hard plastic material</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Indicates joint separation</td>
<td>Precise</td>
<td>Discourages user interaction</td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Professional, bright, neutral</td>
<td></td>
<td>Identity carrier for the company product range</td>
<td></td>
</tr>
</tbody>
</table>
8.1.3  Syntactic Functionality Analysis

A syntactic functionality analysis is conducted on the same industrial robot as in the semantic functionality analysis. As the analysis is based on only one product, the syntactic functions included in the analysis is limited to discerning, connecting, uniting and balancing leaving out referring. These functions describe how form entities are visually connected through the structural composition of the design. The analysis aims to investigate what design features can be found, the underlying reasoning and how this is interpreted by the user.

While analyzing the design of the company’s robot it is quite clear that major parts of the robot does not correlate to the existing design guidelines. Color and certain small features are kept but when comparing the design elements to the more traditional robots it can be difficult to see the resemblance. As of now there is only one such robot, meaning that all the decisions must be made exclusively based on that product’s features. A larger sample size would ease the process of extracting relevant design elements. Additionally, many of the main design features of this robot can be found while examining the arms. These are not always applicable to an autonomous mobile robot since their geometry is vastly different.

Nonetheless, it is at least possible to notice that some of the design choices were made based on the guidelines created for industrial robots. The colors correlate to the other product categories and some surfaces match the description in the existing design guidelines. An illustration of the analysis is presented in Figure 30.

Based on the analysis several syntactic functions are identified. The most reoccurring functions are connecting and balancing. These functions are most likely easy to implement which creates a visual harmony within the design. As symmetry naturally occurs within many design features it is also most likely that these symmetries are identified. The connecting syntactic function also creates a visual link between two shapes on each side of a form element, which frames the design. This is particularly visible on the first and fourth illustration from the left in Figure 30. It is also noted that color is an efficient way to create discerning syntactic functions which communicates a difference in either functionality or mechanical properties. Additionally, the uniting syntactic functionality is considered a powerful property to visually connect two separated form elements, as seen on the third illustration from the left in Figure 30. Even though the shapes are slightly different, they are still clearly connected by their fundamental silhouette.

![Figure 30: Syntactic functionality analysis of the company industrial robot](image-url)
8.1.4 Design Format Analysis

The design format analysis as described in section 5.4 is used in this thesis to analyze two different categories of products. The first one aims to see which design features are present on existing industrial robots produced by the company and the other one looks for the same features but on products other than robots. A slight modification to the analysis is done to better fit the scope of this case. Instead of having three levels, being strong occurrence, weak occurrence and not applicable, a fourth one is added which is used when there is no occurrence. The reason behind this is that since there are many differences in the designs of the products, mainly between robots and the other product categories, there is a rather high risk that certain design features will not be present. So, in total, strong occurrence gives two points, weak occurrence gives one point, no occurrence gives zero points and if it is not applicable it will not be counting towards the total amount of products for that feature.

With the explicit categories introduced by Andersson (2016) as a base for the categorization, a number of different design features are put under each category. In the analysis main form, details, graphics, colors and graphical user interface are included. The last category is only relevant in the second analysis of various products. The included design features are derived from the case company’s existing design guidelines. Due to the confidentiality agreement with the company all information about the products and features included are left out. However, the result is still shown to give an idea of what insights are derived from the model. The results can be seen in Figure 31 and Figure 32 respectively.

As can be seen in the figures below, the analysis of the robots shows that design features included in main form, graphics and colors are the most reoccurring. As for the analysis of various products from different categories graphics and colors have the highest score. However, the results from the graphics section of the various products is mainly an outcome due to a high number of features not being applicable, which must be taken into consideration. It can still be concluded that design features part of the graphics section is consistently used across the analyzed products, which should be taken into consideration when designing new products. It might be the result of graphical elements being easy to transfer across the product portfolio and is therefore utilized as frequently as possible. It might also be the result of graphics being a particularly strong and easily recognized identity carrier, creating a visual congruence.

The occurrence of the design features existing in the design guidelines at the case company of the industrial robots (Figure 31) is at an average total of roughly 73%. This is calculated adding the occurrence in percentage of the right column and dividing by the number of design features. For the various product analysis (Figure 32), the occurrence is roughly 70%. In this case it is again good to note that the “not applicable” category might cause the result to have some margin of error. For example, one of the design features in the graphics category is only applicable by one of the five products, resulting in a 100% score. The total occurrence across all analyzed products is roughly 72%. The conclusion is that in general, the design features represented in the company design guidelines are well represented across the analyzed products. This is a strong indication that the visual brand language is of high importance for the case company.
Figure 31: Design format analysis done including four robots from the company

<table>
<thead>
<tr>
<th>Main form</th>
<th>Details</th>
<th>Graphics</th>
<th>Colors</th>
<th>GUI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 66%</td>
<td>2 25%</td>
<td>8 100%</td>
<td>8 100%</td>
<td></td>
</tr>
<tr>
<td>6 75%</td>
<td>5 65%</td>
<td>8 100%</td>
<td>8 100%</td>
<td></td>
</tr>
<tr>
<td>6 75%</td>
<td>4 50%</td>
<td>7 66%</td>
<td>8 100%</td>
<td></td>
</tr>
</tbody>
</table>

Strong occurrence  (2 points)
Weak occurrence  (1 point)
No occurrence  (0 points)
Not applicable

Figure 32: Design format analysis including five products from various categories from the company
In the analysis it can be seen that some of the products do not correspond well to the design features. Naturally, this can be due to the chosen features not being optimized for the selection of products. That being said, while maybe not done in a wide enough extension, this format seems to be useful when determining identity carriers for a company with the branded house strategy. Thus, proving to be a good method when there is little to no prior knowledge internally about previous design choices.

It should be noted that the results show that doing this kind of analysis is best suited products within the same category or product family. This due to higher variance, at least in this case, leads to a less reliable outcome since a high number of design features not being applicable will affect the end result. It goes in line with the original framework by Warell (2001) who suggests analyzing product families or a product over different generations.

The result from the design format analysis is used to create the basic design principles for the most important design features, derived from the existing design guidelines at the case company. This is further elaborated in section 8.4.

8.1.5 Architecture Analysis

An architecture analysis is utilized to better understand the physical elements and their relationships of autonomous mobile robot design. Ulrich and Eppinger (2012) suggests a four-step method to establish the product architecture, as described in section 5.6.

For this work it is considered enough to follow the three first steps of the method as the main purpose part of the thesis scope is to create an exterior design and not a completely defined mechanical structure. The fundamental and incidental interactions are instead roughly established while clustering the various physical components.

The product schematic is a collection of the constituent physical and functional elements of the design. The components are divided into functionality categories, which are mechanical structure, component interface, navigation system, propulsion system, digital communication and human-machine communication, see Figure 33.

![Figure 33: Product schematic](image)
The elements are clustered into chunks. These chunks show the connection between the components. The clustered elements are presented in Figure 34. The model is adapted to better fit the project. The clustering criteria was considered but not articulated in the illustration as it did not provide any further useful information in the model. The connection between the various components is defined as either geometric integration (meaning a direct physical connection between the elements) or non-contact interaction (meaning a connection that is possible to achieve even though that the elements are physically separated, e.g. cable-based and wireless connection).

The clustered elements are used to define and articulate the system and is used during the ideation and concept generation. By using the component clustering schematic the necessary physical components are included and considered in the design. In particular, the relationship between the components is helpful when defining concepts. If two elements share a geometric integration, it is easy to conclude that these elements always will share a physical constraint and that the interface between these elements always need to be established. The component clustering schematic is also used as a communicative tool when expressing the system requirements internally during the product development process. As these products are rather complicated and with many internal components and connections, it is easier to use this type of schematic to systematically discuss and evaluate the product architecture.

![Component clustering schematic](image)

*Figure 34: Component clustering*
By using the established relationships between the constituent elements, a rough geometric layout is established. The purpose of the layout is to determine the feasibility of their positioning and the chosen clusters can be analyzed. The geometric layout is illustrated in Figure 35 and Figure 36.

**Figure 35**: Rough geometric layout of an autonomous mobile robot showing the geometric placement of the charging system, batteries, logic board, sensor platform, propulsion system and lower support structure. Note: The logic board is disproportionately large in this particular schematic.

**Figure 36**: Rough geometric layout of an autonomous mobile robot showing the geometric placement of emergency stop buttons, laser lidar sensor and top support structure.
The rough geometric layout was created with assistance from engineers at the case company. There are several insights from this analysis. Batteries with enough capacity for the application are heavy and will correspond to a majority of the total weight of an AMR. For the design to be stable these batteries should be placed as close to the ground as possible. The logic board needed for autonomous drive on the other hand is quite small, lightweight and doesn’t generate much heat. Therefore, the logic board can most of the time be placed wherever it is deemed easiest within the construction.

The sensor platform is a collection of several various sensors that can be used by AMRs, including visual (camera-based), ultrasonic and laser sensors. In addition to the sensor platform a LIDAR-sensor (Light detection and ranging) should be utilized. The lidar sensors generally provide a 270-degree field of view in the horizontal plane of the sensor. The field of view is at a slight angle, see Figure 37. This means that the design features of the AMR should not restrict the field of view of the lidar. It also means that the lidar cannot be placed too close to the ground, as it then will identify the floor which will cause a malfunction. The camera sensors should be placed as high as possible, which allows for a superior object recognition. The laser sensors can include so called time-of-flight cameras, which sends out laser pulses which bounces on surrounding objects. These laser sensors are quite cheap and small and can be placed almost anywhere on the design where additional field of view is required. The time-of-flight cameras can be covered with an IR-glass if necessary for the design.

![Figure 37: The working principle of a lidar sensor. On the left a sideview of the slight angled field of view in the horizontal plane is illustrated. On the right the 270-degree field of view is illustrated.](image)

### 8.2 Case: Product Development

This section includes the methods and process for developing the new AMR product for the case company.

#### 8.2.1 Interview with a Lead Designer

Early in the product development process an interview with a lead designer at the case company is held. The aim of the interview is to better understand the current visual brand identity and design DNA and also to discuss the existing design guidelines of the company. The aim is to better understand the result from the design format analysis described in section 8.1.4. In the existing design guidelines, it is specified how shape and layout, materials and finishing, colors, logotype application, rating plates and packaging and user interface should be applied for new products. The interview is semi-structured, meaning that questions was formulated prior to the interview, but with room for follow-up questions (Osvalder, et al., 2015).

The lead designer has over 15 years of experience in the case company, and has worked in several departments, including product development. It is through the initiative of this designer and a cross-functional team that the existing design guidelines were created as a
communication tool between various departments. Simply put, the design and user experience division felt that much of the result from the product development process got lost along the way as projects were transferred between different divisions and departments. They identified the opportunity to use design guidelines to prevent this and to unify the design language of their different product ranges.

The interview generates several key insights which is taken into consideration throughout the development process. The interviewee put emphasis on the desire to unify the visual brand language and that all products that are created under the case company’s brand should be fundamentally connected through the design language. This implies that the category extension of autonomous mobile robots also should follow this cohesive visual brand language, meaning the branded house strategy. As of now the case company do not have any visual differentiation for high-end and low-end products.

Through the interview concrete advice about which key design features to incorporate into the design is given based on the existing design guidelines. The case company do not utilize natural, softer shapes and is instead using sharper edges combined with straight lines, whole shapes and very seldom any splitting lines. Chamfers are also common.

It is also mentioned that the design guidelines should be seen as an inspiration, and not as rules. Some design features such as the logotype placement and combination with other colors are to be strictly followed though. Equally important is the use of the same color palette as the case company, which is expressed to be a key identity carrier. The results and insights from the interview are used throughout the product development process. It is also used to create the design principles based on the existing features of the company’s existing design guidelines, see section 8.4.

8.2.2 Ideation

Throughout the creative phase of the thesis multiple ideation sessions are held and performed by the authors of this thesis. Each session focuses on a specific theme which ranges from modularity and functional design to aesthetically pleasing forms. This creative design work is done in iterations so that each area can be explored as thoroughly as possible.

The sketches produced during the different sessions are used to get a better understanding for which design features should be used and why they must be used in some circumstances. During the ideation, conveying ideas and abstract thoughts are made easier to grasp when illustrated with simple drawings. Therefore, ideas can be taken further with the help of simple sketches.

The first ideation session focuses on creating various forms, shapes and silhouettes that are subjectively aesthetically pleasing. This session was held very early in the process and had therefore not much knowledge to base the ideas on. The product expression, scale and proportionality are explored combined with different shapes and lines. As there is no frame of reference of what could be considered a suitable design of choice, it is obvious that there was a need for more knowledge of the application area for the robots.

The second ideation session focuses on modularity and functional design, based on the insights from the theoretical framework in section 4.4. During this session the holistic exterior design is not in primary focus. The aim is to find possible solutions for various joints and modular elements with functionality in mind. Two main types of modular architectures are explored:
The bus-modular and the sectional modular architectures. The first is explored by using modular chunks such as interchangeable components incorporated into the exterior chassis. This could include interchangeable lights, sensors, cameras etc. The sectional-modular architecture is explored using reoccurring interfaces between components, such as snap joints, hinges and screws.

Following the two ideation sessions, several smaller sessions were held each week until the workshop sessions which was held in the middle of the thesis process, described in section 8.2.4. The focus is different for each iterative session. By both looking on the whole product and the detail of the component interface it is made possible to better define some ideas and potential concepts. One important idea started to form during these weeks: By using modular corners and a flat surface connecting them, the length/width can be altered with little effort. By also using a sectional-modular stacking system of these base configurations, different heights of the mobile platform can be achieved.

Throughout the different sketching sessions many different ideas are explored and a sample of them can be seen in Figure 38. To see all of the sketches see Appendix C.

8.2.3 Moodboard
As part of the ideation phase three moodboards are created. The first moodboard, called Visual Style and Finish is created with the aim to clarify the sought-after exterior finish, such as material, texture and reflectiveness. The moodboard is created with the existing guidelines of the case company in mind. The second moodboard, called Value Words, shows the company’s words of value in conjunction with pictures which represents a feeling which resonates those words. The last moodboard, called Modular Design, focuses solely on modularity and how modular products can look like in practice. The Visual Style and Finish moodboard is presented in Figure 39. All of the moodboards can be seen in Appendix D.
These moodboards are used during the product development process to communicate the product expression, the visual brand identity and brand values and modularity categories connected to the case. They are also used during the workshop at the case company.

8.2.4 Workshop

Workshops are held as a complimentary way to gather ideas during the ideation phase. Partially since it can increase the range of ideas being created and to include a greater variety of competences and thus exploring more unique ideas. A workshop can be described as a creative meeting with the intent to gather people within a specific target group, experts or people with no connection to the topic and together they can explore a category. During the workshop the accumulated creative potential within the group can be utilized to discover current problems, desired futures or possible solutions within a given theme. (Nilsson, et al., 2015)

To better define the workshop the purpose and aim must be established. This is done using the WWWWWh-method, meaning asking the questions: Who, What, Where, When, Why and How (Boeijen, et al., 2013). Normally this method is used to define a design problem. However, it is altered to this context, where the same questions are used to define the reasoning behind the workshop. The application of the WWWWWh-method is shown in Appendix E. Using the WWWWWh-method, it was established that the aim of the workshop is to understand how design is viewed at the company across multiple departments and to generate new concepts based on the first draft of the developed design guidelines.

In total two workshops are held at different occasions as well as one trial workshop without any other participants other than the authors of this thesis. Firstly, one test workshop together with master thesis students at the case company is conducted to get a better idea for the time

Figure 39: The Visual Style and Finish moodboard, showcasing the desired material, texture and finish for the products exterior
needed for each activity. Also, this gives an initial impression of what result to expect from the workshop and if any part needs to be clarified further. The second one is done together with personnel from the user-experience and robotics department.

The workshops started with an introduction of the session, explaining the agenda, the purpose of the workshop and the basics of autonomous mobile robots. The instructions and material used during the workshops can be found in Appendix F.

Several ideas generated during the workshop are useful in further development. This includes e.g. mechanisms which allows the robots footprint to be shifted, using a common interface for parts to be exchanged easier and utilizing a leader robot and many smaller ones with a swarm-like behavior. Further, many of the ideas enforced previously explored ideas from the sketching sessions. For example, some participants explored using corner modules as a structural element using aluminum extrusions. Another participant explored the possibilities of using the wheels as structural components, acting as both a propulsion system and as a fixture. Seeing how ideas with comparable characteristics are formed during the workshop is beneficial for verifying the results which existed prior to the workshops.

With all of the contents extracted each idea is grouped into several categories. These categories being functional design, user-centered design, aesthetics, protection, industry application, cooperative robots, adjustability and configurability, see Figure 40 for one example. This gives a better overview for when and how each idea could be implemented and helps greatly in the upcoming concept creation sessions. All of the ideas in their grouped state can be seen in Appendix G.

![Cooperative Robots](image)

*Figure 40: The result from the workshops showing cooperative robot ideas*

The most valuable contribution of the workshop sessions is the creative inspiration that is created as a result. All of the participant was excited to be included and worked hard to provide a good result throughout the sessions. The participants provided a fresh approach to solve the
design, which is taken into consideration. Furthermore, as the amount of material generated during the workshop was overwhelming, it required structure to process all of the information and ideas. The grouping of ideas into categories helped the product development process going forward into concept generation.

8.2.5 Mock-up

Mock-ups are created to get a sense of silhouette, shape, form and size. The models are made out of cardboard boxes and created in 1:1 scale. To make the initial scale and size of the mock-up feasible, the average height, length and width of AMRs from the proportion analysis in Table 7 is used as a reference. The base dimensions are set to roughly 750x550x300 mm. The mock-ups are created with three basic forms as a base. This includes a bottom box, a divider in the middle with room for full lidar range and a top box. This increases the understanding for how certain shapes, both for lower and upper parts of the platform, changes the overall visual experience. It also enables tests showing how low the lowest configuration is perceived and what happens when many levels are stacked on top of each other.

As for the bottom part, two different designs are created during the mock-up stage, see Figure 41. One is a rectangular cuboid with straight faces. The other is similarly shaped but with an angled slope at the bottom of the platform. For the top, a total of four different designs are made, see Figure 42. Two are the same configurations as the bottom part, and two are more experimental and does not allow for the same level of storage efficiency. Thus, 10 configurations can be made.

At this stage it could be concluded that adding an inwards slanted angle to the bottom of the platform is preferred over making it go straight down. It gives a sense of mobility without looking unstable while in contrast it looks stationary with a wider base. As for the top part, when more levels are added on top it is concluded that the preferred design should be flat and utilize the space as much as possible where the structure ends. That is also good from a modular standpoint since slanted sides, which converges inwards, will unable stacking more levels without the requirement of more customization for each part. As the area decreases so does the functionality.

![Figure 41: The two different designs for the bottom part](image-url)
8.2.6 Concept Development and Refinement

Before creating any concepts, the area of application for where the planned product is to be used need to be defined to set up a context for the AMR. In total, three such areas are defined based on the insights from the workshop sessions. Said areas of applications are called: transport on demand, logistics and industrial production. Each of them has different priorities which and needs to be taken into consideration. A radar chart is used to pinpoint how much focus should be put on each aspect in application. In the chart the axes are: modularity, design importance, user interaction and level of autonomy. This, together with the previously gathered ideas, is used to define which design features should be present and how they differ from each other. The logistics concept is shown in Figure 43. All three different areas of application can be seen in Appendix H.

With the areas defined the next step is initiated, which is to create concepts for each of the found areas of application. However, due to time constraints and advice from the supervisors only one of these areas is explored. The one deemed most reasonable for the purpose to make it as modular as possible is the logistics application, as per request from the case company. It is considered that this area would be able to utilize the configurability of a modular robot.
platform to the highest extent. Thus, that is the area which the concepts are generated towards, with a high focus on modularity and level of autonomation.

The first iteration of concepts is made individually between the authors of this thesis, as to not influence any ideas too early. Some of the sketches are shown in Figure 44. During this first iteration the wheel-module concept is explored, meaning using the wheels and corners as the basis for a configurable design. This is based on insights during the ideation sessions and the workshops. By only scaling the side length, any number of length/width ratios can be created using the same corner/wheel module. Similarly, a sectional-modular design is explored (see top-right corner of Figure 44) meaning that several basic modules are stacked horizontally for different configurations by sharing a unified interface.

The number of wheels included are also explored. Any design which does not include a squared base design is interpreted as difficult to produce. The main reason for this is the changing angles of the corners when for example two sides are scaled (see the top-left illustration in Figure 44.) This means that every new length/width configuration requires a new corner module. The visibility of the wheels is also explored in three configurations: enclosed, corner-based wheelhouse and side-based wheelhouse (see the middle-right illustrations in Figure 44).

The insight from this is that a corner-based design disrupts the continuity of the design, while also exposing the wheels to potential collisions, and is thus disregarded. The side-based wheelhouse is also disregarded further on in the thesis. As autonomous mobile robots are omnidirectional (and are normally designed to communicate the intended direction, as found in the product category analysis in section 8.1.1) it will create a confusing pattern of movement for the user. This is because a side-based wheelhouse is believed to be connected to the existing
current product sign of a car. Cars only have two primary directions of movement: Forward and backward. When a car turns, it always does so in with a turning radius. Therefore, if an AMR also features such side-based wheelhouses, it would not be suitable to also incorporate omnidirectionality into the propulsion system. In conclusion it is considered best to choose an enclosed wheel design, meaning the wheels be mostly covered by the exterior design.

Modular add-on components are also investigated, see bottom-left illustration in Figure 44. By not creating an integral architecture around various sensors, cameras or displays, it allows a potential customer to customize their offering according to their needs, thus reducing costs. This property is of high regard for the case company according to later feedback and is taken into consideration moving forward. Lastly various interfaces between components are explored, including rail-based, pin-based snap-joints and screws. As the product is supposed to be modular and scalable, a common connection between various components needs to be standardized and shared. By using e.g. rail-based connections or snap-joints, the relative scale between the components then becomes less important.

Afterwards, all the generated concepts are discussed, altered, removed or combined to create a more well-defined concept based on the insights above, see Figure 45. Then, after a elimination and combination process, a 3D-model is made to visualize the chosen concept. This marks the

Figure 44: Various sketches from the concept generation phase.
starting point of an iterative process where constructive feedback regarding the design is obtained and tweaks are made to improve the design. More emphasis is put on utilizing areas for different functions and giving the product more character than before. Therefore, additional reiterations of research, sketching and experimentation is initiated to come up with more refined ideas and solutions.

8.3 Case: Final Concept

The final version of the concept for a new AMR includes many design features that are based on the findings in the literature review, form analysis methods and on insights generated during ideation sessions, workshops and mock-up models. In this chapter these design features are described and motivated. As the final concept of the autonomous mobile robot is covered by a non-disclosure agreement between the case company and the authors of this thesis, it cannot be shown as a whole. Instead small excerpts of the design are displayed, allowing for some description of the concept in relation to the case study. This chapter discusses the modularity principles, product functions and explicit and implicit design features below.

8.3.1 Product Modularity

The design is based on the principle of using aluminum extrusions as a basis of the modular exterior design, an insight generated during the ideation sessions and workshops. The aluminum extrusions both act as the exterior chassis and as the support structure of the mechanical construction. These aluminum extrusions feature snapping joints which connects two components along the upper and lower sides (see the left and right illustration in Figure 46) which is by definition a sectional-modular architecture. In order to create corner modules, the same aluminum extrusions are bent at a specified angle (see the middle illustration in Figure 46). A wheel module, with a cylindric top, produced by the case company is used in the concept. Utilizing the characteristics of the curvature of this cylinder the aluminum extrusions are bent in the same radius as the top cylinder of the wheel module and mounted on the wheel using the top ledge. Using this principle, any amount of wheel modules can be incorporated, allowing for a wide number of configurations. If the design is supposed to be squared, the corner module is bent at 90-degrees. Similarly, if the base should take the shape of an equilateral triangle, the modules are bent at 120-degrees, and so on.
As aluminum extrusions can be created and cut at any length, the side, back and front modules can be manufactured at any desired length. This in combination with the customizable corner module can generate several different designs for different application areas. The CAD-model of the concept is based on four-wheel modules and a cuboid form. This is motivated by the findings in the product category analysis in section 8.1.1, where most competitors use this configuration. The case company also considers this configuration as most suitable. Simply put, it is the most feasible configuration to visualize and define further.

8.3.2 Functional Design

The construction features a split in the top section. This split is dedicated for the placement of lidar sensors, which are placed in the corners diagonally opposite to each other, see Figure 47. This is to maximize the field of view for each lidar, generating a 360-degree view. This space is also used for a LED-light strip where different types of light pulses can be used to indicate intention, see Figure 48. The lidar-sensors are placed at the top to avoid any possible malfunction related to identifying the ground, as found in section 8.1.5.

Along the front, back and side a signature feature is utilized, called the plateau-shape. The plateau-shape is made with inspiration from prior products from the case company’s robots to act as an identity carrier and referring syntactic function as well as to keep as a part of the design DNA. The plateau-shape is found during the syntactic functionality analysis, described in section 8.1.3. The plateau-shaped covers are exchangeable to allow for customized attachment of different kinds of sensors e.g. camera and ultrasound. Below these covers there is another rim of IR-glass going around the entire bottom of the structure. This is based on the insights from the architecture analysis in section 8.1.5. This provides the possibility for placing different types of sensors behind the IR-glass, such as time-of-flight cameras, depending on how many the customer need for their application. The rounded corners throughout the chassis are also shaped to match the wheels’ turning radius.
8.3.3 The Industrial Design

The design features a flat, neutral top surface which is adaptable for different applications, based on insights in the product category analysis. If needed, the top surface can be attached to an upper level through the snapping joint sectional-modular architecture, see Figure 49. The top level is made with flat vertical sides, which enables further stacking and an optimal storage capacity, as found during the mock-up creation.

The design is based on the generated design principles derived from the existing guidelines of the case company, the insights from the interview and the design format analysis, which is further described in section 8.4. It is made compact but at the same time has a slight inclination on the bottom chassis. This reduces the visual mass, makes it look more mobile and increases the overall character of the product, as found during the mock-up creation. The concept utilizes reoccurring shapes and symmetry to tie certain elements together throughout the AMR. Balancing syntactic functions creates a visual harmony through symmetry as found in the syntactic functionality analysis. The light band and lower sensor band also share similar

Figure 47: The lidar placement on the concept, generating a 360-degree field of view

Figure 48: The Lower sensor strip (left) and the lidar placed in the corner inside the light band slot (right)
silhouettes, creating a connecting syntactic function. This is again based on the insights from the syntactic functionality analysis, where these are found to create a visual link between two shapes on each side of the construction. There is also a rationality regarding the proportionality of several features. The plateau-shape on the front and back covers two thirds of the total height of the lower chassis and on the left- and right-hand sides it covers one third of the total height. An excerpt of the design is shown in Figure 50.

The usage of non-equal distances from the corner to the plateau-shape on the front and back in comparison to left- and right-hand side creates a sense of direction. This in combination with the AMR being longer than wide enhances the forward-facing direction even more. The
proportionality of height/width/length is similar to the analyzed AMRs in the proportion analysis, with a design that is proportionally taller and wider compared to AGVs. Another aspect is the usage of horizontal design features which exist to signify that the AMR is able to move omnidirectionally. All these design choices are based on insights found in the product category analysis in section 8.1.1. Further, the components are placed within the major structure meaning that it has a more enclosed look. Features are also aligned in different levels to increase the overall coherence in the structure.

The usage of color follows directives about prior color usage in the case company, per recommendation found during the interview described in section 8.2.1. This is also according to the findings in the design format analysis, where it is concluded that a cohesive color scheme throughout the product range of the case company is used as a strong identity carrier. The usage of a various shades of grey as primary and secondary color with the logo as an accent color is also commonly found on the market, as found in the product category analysis. This provides a flexibility to adapt to different applications, depending on the case company needs.

The aluminum extrusions are spray-painted in a light grey with reflective finish which gives a more professional, durable and high-end look, motivated by insights found in the semantic functionality analysis. Other design choices are e.g. a brighter top and a darker bottom which puts the visual mass closer to the ground and creates a sense of stability. The darker color also communicates that these areas provide functionality for the product, which is found in both the semantic and syntactic functionality analysis.

8.4 Case: Design Guideline Development

As the concept developed, so did the first iteration of the design guidelines. Some insights of key design attributes were defined and illustrated. These attributes can be described as design principles, rather than design features. The difference between the two is that the design principles does not include an actual product to show how the principles are applied but is rather a 2D-representation. The design principles are the result from the design format analysis, described in section 8.1.4 and the interview with a lead designer at the company, see section 8.2.1. The design principles or the developed design guidelines cannot be shown in this thesis.

Through these design principles it became clear that it was necessary to define which design features should or should not be included in the design guidelines. It also became clear that the design guidelines could not be completed without a finished concept. This is because that the concept and the associated guidelines are a part of category extension for the case company, where no previous products exist from the company. Once the concept had been finalized the actual creation of the guidelines started. In the concept all the applicable design principles are included in the final concepts design. That acted as a good starting point for the creation of the guidelines since it was made easier to determine which characteristics must be kept and to what degree.

The overall design guideline framework, as presented in chapter 7, includes many different design features which can be defined for the product segment. In the case of the design guidelines created for the case company there was little to no focus put onto the graphical part of the explicit design features. This was partially because these design features are explained and detailed at length in the prior design guidelines. The brand identity category was also altered to fit the case application. Instead of including it in the implicit design features it was used to tell the backstory of the design in the company and to introduce their values early on.
This can be altered in any way desired since the created framework should inspire rather than dictate which contents are necessary.

Whether or not all of the features are included in the framework, it is still recommended that a brief explanation, with illustration if possible, is included early so that the reader will understand the relevant technical terms. In the design guidelines developed for the case company the explicit design features are described before the explicit features are defined based on the concept.

Moreover, since everything in the created guidelines is based on the newly designed concept, and there being no previous AMRs in the company’s product offering, a higher degree of freedom could be applied. Therefore, most of the explicit and implicit design features could be applied as planned in the creation of the design guideline framework. Certain features, such as using brand specific colors and the signature plateau-shape are characterized as identity carries and should be present in all of the future products within the specific category. Other recommendations are instead just meant to act as inspiration. An example of this is the usage of horizontal features all throughout the design to indicate the omnidirectionality. How this should be implemented or to what degree is not specifically stated. This is to make sure that new products still maintain a freedom of alterations and variations within the product category. The aim of the design guidelines is to provide enough information and regulations so that new products are interpreted as part of the same product family portfolio.

One of the main benefits of having these guidelines is that any results from the form analyses may be easily conveyed and communicated to others in a suitable format. Industrial design is a complicated aspect of product development, with many variables and uncertainties connected to it. The underlying decisions for a product form are not always easy to describe in an industrial setting, with cross-functional teams featuring different skills and prerequisites. The most crucial decisions about how each feature has a purpose can thus be explained in this industrial environment in a clear way using brief descriptions and illustrations.
9 Discussion

Four main areas of the thesis are discussed in this chapter: the thesis methodology, the form analysis framework, the design guideline framework and the case application.

9.1 Methodology

During the thesis an iterative approach to answer the research questions is applied, as shown in Figure 2. This proved to be one of the most difficult aspects of the process. In the beginning of the thesis there was no prior knowledge regarding design guidelines. This made it hard to know what research areas to explore and include in the thesis. It also made it cumbersome to connect different research areas in the literature review to each other and incorporate this knowledge in the case application. This also affected the product development process, as the ideation and concept generation need to be founded on findings in literature and on the design guidelines. A more structured and linear approach might have made the process more efficient.

A suggestion would be to first clearly explore and define what design guidelines are and how they might be utilized in a product development process. Then a thorough literature review could have been conducted, which would be the foundation of the theoretical framework and design guideline framework. If all elements of the literature review would have been completely defined before the product development process began, it would have been easier to apply the chosen theories. Applying the finished models to the development process could have made the verification of the theoretical findings easier to conduct, which would also have further strengthened the validity of the work.

9.2 Form analysis framework

Parts of the form analysis framework is modified or altered to better fit the product development process. An example of this is the modifications of the product category analysis. The proportion orientation and shape analysis is modified (including only the basic proportionality of the width, height and length) and incorporated in the product category analysis. By doing this, the final product category analysis is quite extensive. A risk connected to this is that one analysis method becomes too wide and starts to overlap into other analysis methods. This risk permeates to some extent the entire form analysis framework. It could prove difficult to implement all the included analysis methods isolated from each other. For example, utilizing the basic product category analysis on competing products, the semantic aspects of the AMR design are described, see Figure 26. This naturally impinges on the semantic functionality analysis. Similarly, the differentiating level of the category analysis could be used to describe both semantic and syntactic properties of these products or even the product architecture.

One of the weaknesses with the form analysis framework is that no tests have been done to see in which order these analyses should be conducted. Therefore, future studies could include testing these methods for form analysis on multiple product categories and performing the methods in different orders each time. This could then result in a better understanding for the overall workflow needed when conducting these form analyses. However, results may show that the order itself does not matter. Instead it could be that each specific case needs a certain workflow for it to be optimized.

A recommendation for other companies that wish to utilize the form analysis framework is to state the purpose of each analysis before the application. This includes what knowledge is
needed, why it is needed and how it might affect the product development process. This way any overlap between the analyses is then intentional and will more likely still be useful and not redundant. It is important to keep in mind what prior knowledge exists at the company and choose the most suitable methods based on this. As an example: imagine a company with clearly defined design guidelines, vast knowledge of product design principles and a structured process to transfer design features within the product portfolio. This company might not need to utilize the design format analysis, semantic- or syntactic function analysis. If this type of company aims to expand into an unfamiliar market, the focus should instead be to understand the commonalities in design and architecture of the products of this market segment. Then the product category analysis, the proportion orientation and shape analysis and architecture analysis are important.

9.3 Design guideline framework
The creation of the design guideline framework is based on the design features that is mentioned in literature. The decision of which features to include is based on subjective assessments. The aim is for the features to complement each other to create a holistic description of product design. Some features are deemed to be too general and non-descriptive, e.g. size and number. Others are assessed to be too similar, such as repetition (excluded feature) being too closely related to rhythm (included feature). In some cases, explicit features are moved to implicit features, such as isolation and weight which in this case are used to describe contrast and balance in the design.

One of the main benefits with the design guideline framework is that an extensive research area has been compressed into an easy-to-follow list, as shown in Figure 21. The framework is also complemented by a description and illustration of each explicit design feature, which removes any ambiguity of the included terms. However, while it does cover many different aspects, some design features are still excluded, as explained above. It is important to keep in mind that this exclusion might have been unconsciously influenced by the case application for the design guidelines. If the included design features are deemed to be lacking, it is possible to add additional features according to need. The design guideline framework should preferably be applied to several different cases in future work for verification and validation. Complimentary research might then be required to fully satisfy all the needs for most product-producing companies.

An identified difficulty with the design guideline application for the case company is the separation of explicit and implicit design features. When describing certain explicit design features, it is tempting to also describe the underlying reasoning of said feature. As an example, describing the small inclination of the exterior silhouette, shown in Figure 50, in the explicit design features feels more natural to include together with the correlating implicit feature (decreasing visual mass). To solve this problem in the case application, some motivation behind the design features are briefly included in the explicit features category (such as semantic and syntactic functionality or product expression). This is then elaborated in full in the implicit design feature category as well.

Furthermore, it is recommended to early on establish what the desired outcome from using the guideline framework is. That will increase the likelihood that it will be beneficial in the design process. A company with little knowledge of design theories might not fully understand, or be able to articulate, the working principles of implicit design features. In this case it might be
easier to first define the explicit features important for the product design. By consciously discussing, defining and utilizing key design features, a greater understanding of product design might be accumulated over time. Another approach for this type of companies is to employ designers with experience of utilizing design in product development processes. These senior designers might be able to translate the existing key design features of the product range, using the form analysis framework, into comprehensible implicit features. Using design guidelines to articulate these findings is then readily available for less experienced staff at such a company.

Lastly, and most importantly, as much as design guidelines are meant to be used as an inspiration, the same goes for the framework. There is not just one correct way to create a set of guidelines, and the framework should be adapted to each individual case.

9.4 Case application

Many of the design choices made for the AMR emerged from theories in literature. Since the main purpose of the thesis is to create design guidelines it only made sense to, in one way, restrict the design process by applying mostly theoretical decisions. That does however not mean that no subjective choices were made as well. Nonetheless, parameters such as length, width and height were all based on the average among competitors AMRs. Syntactic functions, such as referring and connecting are present throughout the design. It ties the whole design together which further proves the usefulness of using such theories.

Additionally, the creation of the design might have been too restricted while at the same time not being restricted at all. On one hand, the case company gave no specific demands for what the design should fulfill. On the other hand, utilizing design theories was a priority. Many of the complications that arose during the thesis could have been avoided if a set of requirements were specified early in the thesis. Instead, due to the degree of freedom which was present throughout the thesis, a less familiar workflow was followed. Normally demands and needs would be translated to a list of specifications. Solutions, through design, would have been made to solve these. This could have resulted in the project being vastly different. It would have been interesting to see how the design would develop and take shape if specifications for the product design would have been specified early in the development process. This would also have made the verification of the chosen concept easier to perform.

One aspect that might have had quite a large impact on the final design and results is the fact that the three different areas of application, as described in 8.2.6, were not explored equally. Due to the recommendations from supervisors two of the three areas of applications were eliminated early on and no concepts were made in those areas. If enough time was given, other solutions could have been explored and contributed to a better, or at least different, result. Similarly, the chosen area of application was quickly processed and defined in only one concept, again due to time constraints. After the concept was defined it was improved iteratively until the final concept design took form. Yet again, a wider approach and several defined concepts, which could have been evaluated compared to a specification list, would increase the validity of the result.

Further, it was established during the research phase that the case company’s products are easily identified by their color and usage of logo. It can be concluded that these are suitable as identity carries and helps customers distinguish products from different companies from each other. However, an identified problem is that these identity carriers are quite anonymous on
the market. Most of the competitors utilize similar color schemes with smaller alterations. The developed concept design has been influenced by the prior existing design within the company. Everything from the general silhouette, shape of the corners, surfaces and details been kept in line with what defines the company visual brand identity. However, it is still is difficult to claim that the concept would be easily identified and connected to the case company without the proper color and logotypes applied. This might due to the AMRs featuring several key features that cannot be strayed from, because of the application area and expected functionality.

A recommendation for other companies, aiming to translate the existing visual brand identity into a new product category, is utilizing color and logotype efficiently corresponding to the existing product range. As concluded in the literature review, when subjected to heavy changes, customers tend to not like them at first. As such, it is important to know what to keep and what may be discarded. Certain product categories allow for more variations than others, but using matching colors and logotype is easy to apply for a new product category, making the new design easier to accept for customers. More extensive research on different types of products and markets is needed to make a better conclusion on this matter. Using the form analysis framework on internal factors will increase the understanding of key design features that should be translated into the new product category. These insights should be translated into design principles and used during the product development process, allowing the visual brand identity to efficiently be translated into the new product category.
10 Conclusion

The purpose of this thesis is to create a guideline for conducting form analyses and to develop design guidelines for branded products. As a part of the thesis, a concept is developed envisioning the visual brand language of the case company, while also serving as the foundation for the design guideline development. The thesis presents three main contributions: A form analysis framework, a design guideline framework and the case application of these frameworks for autonomous mobile robots. Two research questions are answered in this thesis.

RQ1: What strategies could be used to analyze visual form and product design as a part of a brand extension strategy for a product-producing company?

The form analysis framework presents six different analyses as a part of the literature review: product category analysis, semantic functionality analysis, syntactic functionality analysis, design format analysis, proportion orientation and shape analysis and architecture analysis. These analyses, if used in combination, can provide a holistic understanding of the visual form of product design in a brand management context. The framework can be seen as tools a product-producing company can utilize to analyze, understand and articulate design features of products. The form analysis framework examines both implicit and explicit design features and is based on design syntactic modeling. By using the framework internal, external and product family factors are investigated and defined. The generated insights and knowledge of the visual form can then be utilized during the product development process included in the category extension strategy for a product-producing company.

RQ2: How can an existing visual brand identity be utilized during the product development process and redefined for new product categories?

Through the form analyses as a part of the case application it is shown how visual brand identity can be utilized during the product development process. It is achieved through a combination of analyzing the company’s existing product portfolio, examining the existing design guidelines and cross referencing the information during an interview with a lead designer. Results showed that many of the features described by the interviewee and analyzed in the design format appeared within the product range when applicable. This data was then compressed into a set of design principles. These acted as the first set of design guidelines which were deemed most defining for the company’s brand.

Combining these design principles with the insights generated from the rest of the form analyses provided the foundation of the visual brand identity for the AMR product category. The concept envisioning this identity is considered to represent the company, both on an objective and subjective level. Two key features stood out which were color and usage of logotype, which is concluded as being among the most qualified design features to be used as identity carriers. This can be strengthened by incorporating a signature feature, however that might not always be applicable.

The design guidelines are developed using the design guideline framework. By using a combination of explicit and implicit design features, a holistic vision of the visual brand identity can be established. Utilizing design guidelines enable a company to reuse key design features, which will make future product generations recognizable on the market. With these findings, the design guidelines were created to transfer and communicate the most crucial design features of the AMR concept to future product category.
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## Implicit features

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Appendix B – Competitor analysis
Competitor analysis
Analyze design features of competitors mobile platforms

Competitor analysis
Tomas Andersson
Oskar Castillo Ellström
An important identity carrier is the color scheme of product. The color and textures of a product is one of the first thing a user perceives. By comparing the color scheme of different competitors within the mobile platform market, similarities and differences can be identified.

Color is in this analysis categorized into three categories: Primary, secondary and accent colors (see the figure below). Several competitors use some sort of LED-lighting in their product, and this color is also visualized.

The primary, secondary and accent colors and LED-lighting of 24 different models are identified and compared in the table, when applicable. The color distribution is calculated in the lower part of the table, giving an indication of how colors are used today.
Propotion analysis

By analyzing existing products made by competitors, a general understanding of key design aspects can be determined.

That said, the feature proportion analysis is considered suitable for the comparison between the base dimensions of various models. By separating the AGV-robots from the AMR-robots, the differences between the two categories can be distinguished and analyzed.

The length, width and height of 7 AGVs and 8 AMRs are compared in the graph below. The values of the width and height is then divided by the length of the product, calculating the relative proportion.

From the analysis two major conclusions can be drawn. Both the AGV and the AMR are displaying properties of a rectangular cuboid. Only one of the compared models (Robotnic RB-1 Base) are completely symmetrical regarding the xy-plane as is has a circular shape.

The second conclusion is that the AMRs tend to be proportionally taller and wider, which converges towards a cubical shape. This is particularly obvious when comparing the average proportion between the width/length and the height/length. Here the average AGV width is roughly 1/2 the size of the length and the height corresponds to 1/4 the size of the length. Similarly, the average width of the AMR is roughly 3/4 of the length and the height roughly 2/5 of the length.

<table>
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<tr>
<th>AGV</th>
<th>Model</th>
<th>Length</th>
<th>Width</th>
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<td>1300</td>
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<td></td>
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<td></td>
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<td>676</td>
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<table>
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<td>589</td>
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MiR 200 and 500 are two AMRs created for the industry, logistics and hospital application. The MiR 200 and the MiR 500 can carry up to 200 kg and 500 kg, respectively. The models share some crucial design features, connecting them by the use of colors and LED-lights.

**Main product form**

- Rectangular base divided into a top and lower section
- Circular chamfer along the top edge
- Flat sides and top surface
- Rounded corners

**Primary**

**Secondary**

**Accent**

**LED**

**Main product form**

- Long rectangular base divided into a top and lower section
- Flat top surface and indented lateral- and short sides
- Rounded corners
MiR 200

The MiR 200 features a rectangular base which is divided into a top and lower section. The model features a circular chamfer along the top edge and rounded corners.

Modules can be mounted on the top surface such as lifts, conveyors, racks and bins in order to adapt to different customer demands.

The lidar sensors (SICK microScan 3) are placed in between the top and bottom part on two opposing corners yielding a 360° vision. The platform also uses an Intel Realsense 3D-camera for object detection. Ultrasonic scanners are being developed for detection of transparent objects.

**Dimensions:**
Length: 890 mm
Width: 580 mm
Height: 352 mm

**Proportion ratio:**
Width/Length: 65,2%
Height/Length: 39,6 %
The MiR 500 features a long rectangular base divided into a top and lower section with rounded corners. The MiR 500 is developed mainly for industry and logistic application, where a pallet-module can be mounted on top of the robot.

The lidar sensor (SICK safety laser scanner) is placed in between the top and bottom part on two opposing corners. The platform also uses 3D-camera Intel RealSense D435 for object detection. Ultrasonic scanners are being developed for detection of transparent objects.

**Dimensions:**
Length: 1350 mm  
Width: 920 mm  
Height: 320 mm  

**Proportion ratio:**  
Width/Length: 68,1 %  
Height/Length: 23,7 %
The Evo Oppent is a manufacturer using a modular system to create different products for targeted markets. The base and propulsion system is used as a foundation, and various modules mounted on the base for different applications, e.g. industrial rollers, textile industries, robot manipulation or transportation.

The Evo Oppent product family is a good example of a modular design language transferred between a multitude of products. They share most design features, but with some modified elements for different applications.

Main product form
- Long rectangular base with slightly rounded corners
- Glossy grey material
- Sharp top edges

Main product form
- Long rectangular base with slightly rounded corners and a protuding top module
- Glossy grey material
- Sharp top edges
EVO cart

The EVO cart features a long rectangular base with slightly rounded corners. It is mainly aimed for hospital application of lifting and transporting bigger carts and trolleys. The EVO cart can be configured in six different sizes, depending on the customer requirements, ranging from a payload of 200 – 2000 kg.

Dimensions of one of the configurations:
Length: 1657 mm
Width: 602 mm
Height: 352 mm

Proportion ratio:
Width/Length: 36,3 %
Height/Length: 21,2 %
The EVO cobot is similar to the EVO cart, but configured with a mobile operator module. This is a suitable example of how the base can be modified according to the application.
The Clearpath Ridgeback an omni-directional platform created to handle larger payloads. One suitable application is for the customer to mount a robot manipulator on the platform sold separately.

The Ridgeback uses Lidar sensor for navigation (LMS111 laser range) which can optionally be mounted on opposing corners, yielding a 360 field of view.

**Product main form**
- A base that is slightly rectangular from the top view
- A larger black base separated from a smaller top plate
- A yellow surface on the lateral sides
- Rounded corners with large radius
Clearpath

The ridgeback is robust-looking, but has no other mobile robot to be compared to from the same manufacturer. It features a base that is slightly rectangular from the top view and rounded corners.

Dimensions:
Length: 932 mm
Width: 793 mm
Height: 298 mm

Proportion ratio:
Width/Length: 85.1 %
Height/Length: 32.0 %

- Flat top and lateral sides
- No visible wheels
- Two holes placed on the top plate for cable management
- Yellow cover plate on the lateral sides
- Vertical line separates two meeting surfaces on the front lateral sides
- Four symmetrically positioned emergency stop buttons on the front and back
- Two horizontal cutouts for the LED-strips symmetrically placed on all four corners
- Front ending in a vertical ledge
- Flat top and lateral sides
The models Otto 100 and Otto 1500 have quite different design features while some minor parts can be seen in both. For instance, the 100 model is more cube shaped while the 1500 one is lower and longer. The 100 model also has straight sides across the whole chassis while the other one has straight long sides and slightly pointed short sides. The 100 model also has two clearly visible parts of the chassis making it possible to distinguish because of a chasm separating the two.

Main product form
- Flat surface on the top
- Straight sides all around
- Rounded corners
- Metallic surface

Main product form
- Flat top surface
- Long sides are straight and short sides have a slightly outwards pointing look
- Upper half dark grey
- Lower half black
- Rounded corners
OTTO 100 has an integrated lift which enables it to lift objects above the floor. It uses a safety rated lidar and has indicator lights going all the around its body.

It is possible to put attachments onto the top surface enabling it to complete different tasks.

**Dimensions:**
- Length: 750 mm
- Width: 550 mm
- Height: 304 mm

**Proportion ratio:**
- Width/Length: 73.3 %
- Height/Length: 40.5 %
OTTO 1500 uses a safety rated lidar and has indicator lights going all around its body. In comparison to the 100 model it is tougher and more sturdy which makes it very stable.

A lift can be attached to the top which enables it to lift objects above the floor. There is also a conveyor attachment which makes it possible for it to load itself from shelves without human interaction.

**Dimensions:**
- Length: 1810 mm
- Width: 1190 mm
- Height: 400 mm

**Proportion ratio:**
- Width/Length: 65.7%
- Height/Length: 22.1%
Freight from Fetch Robotics is an AMR designed as a modular solution for different applications. The top surface is neutral, allowing for various configurations.

**Product main form**
- A high and rounded, almost circular base
- Top and lower chassis are separated by a horizontal line
- Top chassis: A white matte material
- Lower chassis: A grey matte material
- A matte grey top surface
- A rounded top surface edge
The Freight mobile base is a near-circular platform with a tall base in comparison to the length and width. The Lidar-sensor is placed in the cut-out at the front of the robot for object detection and avoidance.

**Dimensions:**
- Length: 559 mm
- Width: 508 mm
- Height: 359 mm

**Proportion ratio:**
- Width/Length: 90.9%
- Height/Length: 64.2%
The Swisslog TransCar and CarryPick are two platforms designed for healthcare and logistic application. They are both AGVs, as the TransCar moves along set paths in a hospital environment and the Carrypick follows a grid in a warehouse.

The two models do not have many design features in common. The base shape is fundamentally different and except for the use of red strips and the Swisslog logo. Even these elements are differently placed on each product.
The Swisslog TransCar is designed to move carts and trolleys in a hospital environment and can carry up to 500 kg.

The TransCar is an example of how design most probably has been implemented in the end of the development process. There is no apparent color scheme or form that translates within different design features or as a part of the product catalog.

**Dimensions:**
- Length: 1706 mm
- Width: 580 mm
- Height: 330 mm

**Proportion ratio:**
- Width/Length: 34,0 %
- Height/Length: 19,3 %
The CarryPick is designated to move racks between workstations in a logistics or production layout. It moves along a grid that has to be installed before the robot fleet can be operational. Swisslog sells the entire system of racks, grid and software for the customer. No apparent measurements are available on the product site on Swisslog.
The Kuka mobile platforms features a cohesive design language across the Kuka KMP 1500 and the mobile operator iiwa. The use of color and material texture with the same proportionality is obvious at a first glance. Some minor differences can be identified:

- The larger horizontal nock separating the top and lower section is painted black on the mobile operator.
- The mobile operator features some horizontal nock-lines (one that is orange).
- The logotype is not placed in the same location.
- The top plane of the KMP 1500 features four parallel nocks in two pairs on each side (as a result of the lifting mechanism).
The Kuka KMR iiwa (KMR stands for KUKA Mobile Robotics) is an adjustable platform for mobile manipulation where the mobility of the Kuka robot arm can be used at different workstations. One application is in a production environment where orders are placed and transmitted through the KUKA Fleetmanager, where the KMR iiwa picks the order and transports it to the designated station. No dimensions available on the KUKA product page.
The KUKA KMP 1500 is created for material handling in a production facility. The KMP features a long rectangular base with flat surfaces and rounded symmetrical corners.

**Dimensions:**
- Length: 2000 mm
- Width: 800 mm
- Height: 470 mm

**Proportion ratio:**
- Width/Length: 40.0%
- Height/Length: 23.5%
The M-series and P-series are two different types of mobile platforms which have some similarities as well as differences:

- The lights on the P-model consists of four sections, one in each corner. The M-model in contrast has one continuous strip of light going around the whole platform on the upper part of the sides.
- The P-model is more rounded in the front and has sharp edged leading from the sides to the front while the M-model instead had a rounded transition from sides to front but a more pointed front at the same time.
- As for emergency buttons, the P-model has one more in the front and the M-model has one on the sides, located far back.

**Main product form**

- Flat top surface
- Straight long sides and slightly outwards pointing front- and back side
- Rounded corners
- Metallic grey color with dark sections

**Main product form**

- Flat top surface with a circular shape and slight curvature near the edges
- Straight long sides and rounded front- and back side
- Metallic grey color and black sections
- Sharp corners
The M100 is an AMR that can take a payload of 200 kg. It can be utilized for various tasks through modular top configurations.

**Dimensions:**
- Length: 740 mm
- Width: 500 mm
- Height: 210 mm

**Proportion ratio:**
- Width/Length: 67.6 %
- Height/Length: 28.4 %

- **Dark plastic cover following the curve of the chassis**
- **Three circular shapes, probably housing sensors**
- **Light strip going around the edge**
- **Wheels not visible**
- **Slightly elevated part on the top surface**
- **Gradually increasing indent with rounded edges**
- **Cut-out for LiDAR sensor**
- **Flat surfaces**
- **Rounded corners**
The P500 is an AGV using a grid of QR-codes on the ground for navigation. Unlike the M100 it can only move on preset paths.

**Dimensions:**
- Length: 920 mm
- Width: 690 mm
- Height: 280 mm

**Proportion ratio:**
- Width/Length: 75.0 %
- Height/Length: 30.4 %
The Robotnik AGVS as well as RB-1 Base and RB-2 Base are all very different when it comes to their design features. The usage of their logo, colours and shapes are all different. Apart from the fact that RB-1 Base and the AGVS share the more circular features none of them are reminiscent of each other.

Their specialty is transportation robots for indoor use.

**Main product form**

- Circular, dark (black) chassis
- Two clearly separated parts, one top and one bottom
- Flat top surface

**Main product form**

- A rectangular shape where the longer sides are slightly longer than the short-hand sides
- Rounded edges
- Clearly divided top and bottom part
- Flat top surface
- White colored

**Main product form**

- The body consists of a rectangle and two half circles, one on each end
- On the front and back, on the circular parts, there are clear cut-out separating a top and bottom part
- The circular parts are black and red while the rectangular part is grey
- Flat top surface and straight sides
The RB-1 Base is a mobile platform designed for indoor applications. It can carry up to 50 kg.

**Dimensions:**
- Length: 500 mm
- Width: 500 mm
- Height: 251 mm

**Proportion ratio:**
- Width/Length: 100 %
- Height/Length: 50,2 %
The RB-2 Base model is meant for industry application to help with the logistics. It is more robust and can take a higher payload than the RB-1 Base model.

**Dimensions:**
- Length: 990 mm
- Width: 633 mm
- Height: 450 mm

**Proportion ratio:**
- Width/Length: 63,9 %
- Height/Length: 45,5 %

**Features:**
- ROUNDED EDGES
- RECTANGULAR SHAPE WITH CLEARLY DIVIDED TOP AND BOTTOM AND FLAT TOP SURFACE
- CHAMFER
- SOFT CHAMFER / FILLET
- SLIGHTLY THICKER RIM
- FOUR KNOBS PLACED ON THE TOP SURFACE
- RED EMERGENCY BUTTON
- Slightly visible wheels
- Sensors placed in the chasm
- Rectangular shape with rounded ends for camera placement
AGVS

The AGVS is the heavy duty model manufactured by Robotnik. It is able to transport loads up to 500 kg and is well suited for logistic transport.

**Dimensions:**
- Length: 1750 mm
- Width: 652 mm
- Height: 345 mm

**Proportion ratio:**
- Width/Length: 37.3 %
- Height/Length: 19.7 %
Dorabot has two models, MARS and MOMA. Their goal is to manufacture a warehouse automation robot which uses AI. Their mobile manipulator is mainly used for learning about robotics and research within that field while MARS is a general purpose robot which can move objects around on its flat top surface.

Because of the different kinds of application areas the two platforms do not share many design features apart from having sort of sharp edges in comparison to other manufactures.

**Main product form**
- A white quadratic base form with slightly rounded corners
- Sharp horizontal top and bottom edges
- A cut-out along the body placed centrally on the robot

**MARS**
- Side view
- Front view
- Top view

**MOMA**
- Side view
- Front view
- Top view

- Primary
- Secondary
- Accent
- LED

- A squared base with four angled sides meeting at a pivot ledge at lower end of the base
- A cut-out/nock in the meeting of the two angled sides
- A white base with blue angular forms along the
The MARS model has a quadratic base shape with slightly rounded edges. Mainly white is used for the body and some black details can be seen. There is a clear top and bottom divided by a cut-out along the body.

The main application area is luggage transportation where their AI makes them able to navigate in their environment and reach the desired destination.

It has dynamic obstacle avoidance, collision avoidance. This ensures safety while it operates.
The MOMA model has many different angled plates which builds up its body. This in turn leads to the platform having many sharp corners instead of rounded edges like many other models have.

Thanks to its high degree of mobility and easy access to sensor data, in combination with the programmable robotic arm, MOMA is great for learning about robotics which is one of the main uses.

It has the ability to move in multiple directions and this enables collision-free movement. With the help of 3D vision it can identify targets and obstacles.
Appendix C – Ideation sessions
Ideations session 2
Ideation – iterative sessions
Ideation – iterative sessions
Appendix D – Moodboards
Visual style and finish
Modular design
Appendix E – Adapting the WWWWWH-model

To better define the purpose, aim and structure of the workshop, the WWWWWH-model is used (Boeije, et al., 2013).

What is the goal and purpose of the workshop (Why)?
The purpose of the workshop is twofold. Firstly, it aims to understand how design is viewed at the company across multiple departments, to get more people’s perspective on what kind of design should be part of the new robots. Secondly, the aim is to generate new concepts based on the developed design guidelines. This means that the guidelines can be tested in an early stage in the product development process. It also means that ideas are developed by a multifunctional team, addressing many different aspects of design.

Expected results (What)
The expected results are a combination of the actual workshop and the processing of the outcome. By utilizing the design guidelines with a multifunctional team, the actual usability of the guidelines can be tested and analyzed. Based on this a revision of the guidelines can be done. Furthermore, the ideas and concepts are all based on the guidelines, which is a crucial part of the project. During the workshop the amount of solutions diverges by a multitude of ideas, both addressing the visual aesthetics and modular design solutions.

Further, as a continuation of prior result, numerous ideas and concepts with different levels of detail can be extracted. Both the aesthetics as well as solutions for a modular design will be taken into consideration.

Preparation and time needed prior to the workshop (When)
The design guidelines must be constructed prior to the workshop. A template of the workshop structure will specify how the tasks should be executed and for how long. The necessary equipment needs to be brought to the session, including post-it-notes, sticky dots, pencils, graphite and colored, white board markers, paper (A3 and A4). Instructions and evaluation sheets need to be printed. A presentation on PowerPoint will be created.

Workshop structure (How)
The workshop should consist of several phases which can be done individually or in smaller groups. The phases are introduction, creation and evaluation. In total the workshop should take somewhere between 1 to 2 hours. This could depend on the number of participants.

Introduction
There should be a short introduction firstly to brief the participants of the project scope, the purpose of the workshop and of autonomous mobile robots. The introduction should also include a warm-up session for the creative session.

Creation
To generate ideas, brainstorming, speed storming, brainwriting or brain drawing are all be viable methods to help let the participants’ creativity flow freely during a short amount of time. Concepts should be created with the design guidelines, the case company brand values and product modularity in mind.
Evaluation
At the end of the session, the ideas are evaluated by all participants. The evaluation should be simple and time-efficient. All participants get a chance to see all selected ideas and if necessary, get an explanation of the idea. Each participant then is given 2-4 sticky dots and assign them to the most promising ideas. Only one dot per idea is allowed.

Ending the workshop
In the end the purpose must be explained once more. Lastly the participants should be thanked for their attendance and cooperation.

Required participants (Who)
The ideal case is to incorporate as many different competences as possible to cover a wider range of ideas during the workshop. This mean that the participants can stem from the Robotics-, UX-design-, Industrial design-, Marketing- and Management departments. The number of participants during the workshop should not exceed ten people. This is to make sure it will not take up too much time and to make the process of analyzing the data less complex.

Suitable location (Where)
The workshop should ideally be held in a creatively stimulating environment where there are whiteboards available and tables where the participants can sit down and formulate their ideas. The locale should also be secluded from any noise so that the focus will be kept at a high during the whole session.
Appendix F – Workshop instructions

Estimated total time needed (85-120 minutes)

Agenda
1. Introduction, explaining the purpose of the session, held by the facilitators
2. Quick warm-up exercise to get everyone in the right mind-set. Will be done in two iterations
3. Creative creation phase. Will include three sessions
4. Evaluation phase and discussion
5. Summary and ending

Step 1 Introducing the purpose of the workshop (5 minutes)

Hello everyone! As you may know by now, we are two students from Linköping University and our task is to research about and then update the design guidelines for the up-coming mobile robot platforms. One step towards this is to have this workshop here today to get input from others regarding how well the guidelines work as they are today. We also want to get more creative ideas from others. Continuing, it would be great for us to in a way validate if our current results are useful so we can decide what to do next.

Show slides of the agenda of the workshop and also of the old design guidelines and discuss that they are outdated and why change is needed.

Step 2 Warming up (20-30 minutes)

Before we start we want to help everyone warm up your brains a little bit to make the creativity flow even better and sort of make you start thinking outside the box. Firstly, we will divide you into groups of 3 or 4 people and do an exercise called “3-brain”.

Divide the participants into groups of 3 or 4 depending on the amount of people attending. Then explain how the exercise is going to work.

So, this exercise will help you get a bit energized by making your brain work in ways it might not be comfortable with. Don’t worry, no one will get hurt though. We will have one of you start by sitting on a chair while 3 other people stands around that person, one on the right, one on the left and one in front. The person standing on the left will be asking questions about colors and the person standing on the right will be asking simple math questions, such as summation and subtraction with numbers below 10. All this while the person in front will be doing very, very slow gestures with both of his or her hands simultaneously. Because the human brain works as it does this should make you struggle to answer all the question while also keeping up with the hand gestures shown ahead of you. We will hand out small cheat papers with pre-made questions to keep them simple enough for the task at hand.

Hand out the papers, one with color related questions to the person standing to the left and one with math questions to the person on the right.

We will let this go on for about 2 minutes and then switch the person in the middle so that everyone gets to try it. And the questions on the cheat papers may be asked in any order you like. If the person in the middle manages to answer all of them just come up with your own questions with a similar fashion to the ones we provide.
Start the first session and time it for 2 minutes then stop. Then switch the person in the middle and time 2 minutes again and then one last time for the 3rd person. Do it one more time if the total of participants is 4 in each group.

*Well done everyone! I hope you’re feeling a bit warmer now than before and even more energized and ready to move on!*

*We will now continue with the next warm-up exercise. The idea is that you will be drawing random squiggles such as this one.*

Demonstrate on the board what a squiggle could look like.

*It can be anything like this one but also completely different, there is no right or wrong here. When you’ve done that for about 1 minute we will tell you what to do next.*

*We will now hand out paper and pens for those who need them and then go on with the warm up.*

Hand out A4 paper and pencils.

After one minute tell the participants about the second part of the exercise.

*Now you should add beaks, eyes, feet and a tail to each of the squiggles to make them look like birds.*

Give everyone 2-4 minutes to turn their squiggles into birds

*The reason for this warm up is to make you activate and use the pattern recognition capabilities of your brain.*

*And with that we are done with the warm up and will move on to the creative creation session of this workshop! We will keep the same teams as we had during the warm up since we want these activities to encourage team work and ideation together by sharing your ideas!*

Divide the groups once more if they are too big, make 2-3 groups depending on the number of participants.

**Step 3 Creative session (30-50 minutes)**

Three idea generation will be divided into three areas:

*During the creative session we will have a total of 3 areas to explore through different kinds of activities. We will explain them when it is due time. One more thing, at the end we will be handing out a prize to the team which came up with the most unique ideas, meaning if you just write the same thing over and over it won’t count for more than one. We will reveal the prize at the end of the workshop.*
Session 1 (Moodboard and design guideline format)

Necessary materiel:

- A3 papers
- Post-it notes
- Pencils

Provided inspiration

- Moodboard
- Old guidelines from the case company
- New illustrations of old guidelines

Firstly, we want to see if using the old design guidelines and the case company’s value words can be a good source of creativity when making new concepts for mobile platforms. So now we will hand out a moodboard we made for inspiration, the old guidelines and the value words contained within. Once again, you are allowed to discuss as much as you want during this session within your team and we even encourage that! Write down ideas, draw something or even both. Anything that makes us understand what you want to convey.

Hand out all the necessary illustrations to the respective teams. Also give each team a set of A3 papers and stack of post-it notes. Set the timer to 6 minutes and instruct everyone when to start. After 6 minutes tell everyone to stop.

With that we’re done with the first session. You may put up your A3 paper on your respective designated area for each team. We’ll then move on to the next activity.

Session 2 (Competitors)

Necessary materiel:

- A3 papers
- Post-it notes
- Pencils

Provided inspiration:

- Pictures showing mobile platforms made by competitors
- 2D-views of the platforms showing their silhouettes

Now we will move on to another activity where we once again want you to generate ideas in the same fashion but instead based on mobile platforms manufactured by competitors. You will once again formulate ideas in your preferred way on post-it notes and then stick them onto a new A3 paper. This will also go on for 6 minutes.

Set the timer to 6 minutes and hand out new materiel if anyone needs it. Start the timer and let it go for 6 minutes and then tell everyone to stop when it is time.

Well done everyone! Please put up your A3 paper in your area once again. Now we’ll take a 10 minutes break so you can go get some coffee and feel free to take some fika here as well.

10 minutes break.
Session 3 (Modularity and function)

Necessary materiel:

- A3 papers
- Post-it notes
- Pencils

Provided inspiration:

- Printed architecture analysis
- Printed definition of modularity and examples

Now onto the last creativity session. We will now ideate based on modularity. We’ll give a brief explanation of three different types of modularity and we will also provide everyone with the same information in forms of illustrations and some text.

Hand out the printed papers as the other facilitator explains the concept of modularity.

A slot-modular architecture means that the interfaces between different chunks are different, with the result of non-interchangeable chunks on the same architectural system. (Example: car radios)

A bus-modular architecture means that the interface is the same for all chunks of the architecture system, with the result of interchangeable chunk positioning on the same architectural system. (Example: PCI-e slot on a motherboard)

A sectional-modular architecture means that the interface is identical for all chunks constituting the architecture system, but the chunks are not connected to a single element but rather each other. (Example: floor decking systems, Lego)

With that said I think we’re ready to start. The timer will be set to 6 minutes and it will be done in the same way as before when you discuss within your team to come up with as many ideas as possible.

Set the timer to 6 minutes and start. When 6 minutes have passed tell everyone to stop.

Now we are finished so you may put up your A3 papers on your respective area as seen here on the board.

Step 4 Evaluating created concepts and discuss (10-15 minutes)

Necessary materiel:

- Sticky dots

Hand out 3 sticky dots to each person and explain how they will be used.

We are getting close to the end of the workshop now. The last thing we will do is to evaluate the concepts which have been created during this session. You may all choose one concept which you find the most interesting created within your team from each session. If a more in-depth explanation is required you may talk about it so everyone understands. Then everyone may put up a total of 3 dots on any of the selected concepts. Only 1 dot per concept per person so you cannot stack all 3 on the same even if you love it.
Let everyone pick their chosen concepts and put them on a separate place on the board. Then let them put the sticky dots wherever they want to. Discuss the ideas if needed depending on how much time is left.

Step 5 Summarize the results and conclude the workshop (5 minutes)
Of course, we have not forgotten about the prize and the team with the most points is team X. Congratulations and well done!

Hand out the prize.

Everyone has been a huge help to us and now we will try to summarize all the data gathered during this workshop. We want to remind you of the purpose of this workshop which is to get input from others regarding how well the guidelines work as they are today. We also want to get more creative ideas from others. Continuing, it would be great for us to in a way validate if our current results are useful and so we can decide what to do next.

Lastly, thank you all so much for your cooperation. We bet going through all the concepts and finalizing the results will be very valuable for us in our project!
Appendix G – Grouped workshop results
ADJUSTABILITY

4D printing @ MIT

Soft modularity (resin)

MATERIAL BASED

Material that changes shape, like for example, plastics (it's a thing!)

Self repairing, break & stick

Magnetic. Especially for modularity that needs 2 of a kind

Attachmets, like clamps

ATTACHMENT BASED

Material that changes shape, like for example, plastics (it's a thing!)

Magnetic coupling to attach modules

Soft material

Product
AESTHETICS

AMBITIOUS DESIGN

LIKE IRB SHOULDER

ASYMMETRIC

ROUND

DO NOT USE NOCKS

HEX SHAPE

LOAD WHEEL

TUG H
TECH TUG H

ENCLAD SURFACES

SMALL PROFILE (LOW COM)
CONFIGURABILITY

- Modular design
- Corner 90°
- Corner 45°
- Straight
- Interchangeable boxes
- Systematic

Puzzle-like building

Build buggy 4x4

Main entry box splitting multiple with splitters
COOPERATIVE ROBOTS

System of smart and smaller "dumb" parts where they together create cubbies. A smart can only commit to one but it doesn't literally pull. It acts like a lead & other bots can follow. One smart bot & others can be clump.

Many small robots that work together in a swarm so they follow each other for example collect & store things.

Assembling tiny bots that can form based on how much space we have.

Modularly combined platforms to support larger/heavier loads.

Any regular adolescents can be used.

Study bot so things transfer from one to another.
FUNCTIONAL DESIGN

- **Modular design**
- **Chassis with adjustable footprint for C.G.**
- **Low to lift**
- **Hold stuff in place**
- **Safety cushion**
PROTECTION

Swarf-shield

Good for dangerous transport

Safe-robots (non-mobile) that become mobile in certain situations, like during fire alarm, where they become mobile and help people to evacuate, follow team out

Safe-robot attaches to floor

Securing package

Garage door function

Keep stuff clean

Lid on top that opens when a tag is activated

Imagine soda can in giant filled transport

Aim ship, gimbal that thing inside don't shake or mix up.

Self-loading in trailer

Two arms for assembly while moving

Indoor application

Cargo train

Modular design
USER-CENTERED DESIGN

COMMUNICATING

- Voice controls
  - Easy to use
  - Understanding

DISPLAY

HONESTY

- Self-cleaning robots
  - In industry
  - Cleaning air
  - Office version
  - Mine version

OFFICE APPLICATION

- Office service robot
  - A round and sing
  - For birthday
  - Children

Heavy-duty transfer

- Included weight measurement
- So you see how much

- Top-loaded small bucket
  - See through glass
  - Shield
  - Can see if it is full or not
  - Written at where it will go
  - So you as a human know

100% load
Appendix H – The three areas of application
LOGISTICS

COMMUNICATIONS
- Lights
- Communicate intended path
- Confirm button

Adjustability
- Interchangeable components
  - Automatic change
  - Possible for easy change for user

Configurability
- Dimensions
- Pay-load
- Number of wheels
- Top-module

Design
- Simplistic
- Functional
- Compact
TRANSPORT ON DEMAND

Communication
- Lights
- Sound
- Digital interface
- Communicate intention

Design
- Communicative design
- Aesthetically appealing
- Softer / kinder
- Minimal / Subtle

Configurability
- Limited options
- Model-based
- Secured or not

Protection
- Keep clean
- Keep safe
- Hold in place
INDUSTRY PRODUCTION

INDUSTRY APPLICATION
- Mobile manipulator
- Industry 4.0 P.S.

COOPERATIVE ROBOTS
- Robot to Robot Communication
- Assembly + transport robots
- Object transfer
- Leader and follower

Design
- Basic shapes
- Rational
- Product family design language
- Adjustable stability

Configurability
- Pre-purchase customization
- Base platform and top module
- Dimensions in height
- Basic dimension configuration (Small, medium, Large)

Restrictive area
- Transport bots

User interaction
- Autonomous

Modularity / configurability

User interaction
- Design importance

Adjustable footprint
- Or center of mass

Strong robot arm

Digital restriction
- Human identification