Stroller Service System

How to make customer products sustainable within the planetary boundaries - using the case product ‘stroller’, PSS and a Design Thinking approach

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Abstract

Physical customer products have an environmental impact, such as greenhouse gas emissions, due to the use of virgin resources from cradle-to-grave, especially when the origin of the material is from fossil resources. This thesis aims to create a circular business model, by investigating the product ‘stroller’ and place it in a Product Service System, where the user subscribes to the Stroller Service System. This means that the product gets a service function: ‘transportation of a child’, mapped with a user-centered approach. The main objective is to lower the ecological footprint by adopting a modular design including bio-based material and stainless steel, and also include services to address economical and social sustainability goals. The methodology that is used is divided into two parts: Status Analysis – which consists of stroller related literature study, literature review and case study, and the second part is the Design Process – creating the product-, service- and system design. The results are grounded in user insights, life cycle assessment and co-creation with experts, where the conclusions are that a PSS Model Stroller should be used by 4-6 users which translate to about 15-20 years of usage for the steel layer. The way of refurbishing the strollers is done by contract workers that exist where the users exists, i.e. Ease Stroller Hub, who change the bio-based material in-between the use-phases and hands over the refurbished stroller to the next user. Add-on services of access to car pools and grocery delivery is included in the system to ease the stroller user’s everyday life and is a way to designing out the need of owning a car, to lower the overall environmental impact.
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Foreword

If I allow myself to be a bit personal in this segment before the report begins. I am original a mechanical engineer, educated by Linköping University, who has a tight collaboration with industries such as SAAB (Linköping University, 2018), same company that has an impact on Sweden’s Gross Domestic Product (GDP) (Lindsten, 2018), same company that sells high technology weapons to dictatorship regimes that kills civilians (Arias, 2016). I am not going to be too political, I just wanted to exemplify a true scenario that is real and exist just on the other side of an engineering degree. That illustrates that money rules the world and engineering could be a tool – ‘a cog in the wheel’ if you so will. I understand the advantage of developing this kind of technology in a geopolitical context, with the argument of stabilization, if that is the angel of standpoint. But that standpoint does not matter in my opinion, we have bigger issues than fighting over infringements, something called Climate Change. Product development has big enough cause on climate change if you make something like toys which exist to be entertaining, imagine then products that exist to destroy. Product development needs to be changed in its backbone, where ecological-, economical- and social sustainability has to be in consideration when designing, to be able to change from linearity into circularity.

It would not be honest of me not to mention that the “same” theory of science that SAAB uses could be applied to do good as well. For example, turbine technology which basically is a reverse airplane engine, developed by Siemens, located in the same region, can generate energy from taking care of municipal waste, out of the same engineering competence. I am sure stating what I think is right and wrong here, but I do not want to blame the individual engineer fully for making that choice of occupation, rather the structure.

Behavior change will not be enough to stabilize the climate, it also relies on technological fixes such as Carbon Capturing and Storage (CCS), where society needs the competence of science to focus on this issue. My point is that we should focus on slowing down climate change rather than pouring gasoline on the fire. This is what I will try to do, to create a product that is sustainable, which is not the same as zero emissions, but tags on to the demands of RCP2.6 and the goal number twelve of the UN Sustainable Development Goals. The focused product of this project is a stroller and some of its including systems, I chose it because: a) I believe it has potential to succeed, b) it sends the signals of having one of the first products as a newborn – to be as sustainable as possible and c) it could evoke new sustainable values to the user if I achieve to communicate what I will design in this project.
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1 Introduction

This master thesis in Design – Sustainable Future, explores the environmental impact of physical products, in regard to development, use and end of life. The thesis also investigates if physical products could be improved – mainly in terms of achieving ecological sustainability but including also economical- and social sustainability - by adding services and implementing products in a system. The case product that is investigated in this project is the product ‘stroller’. This work explores what connecting system the stroller affects, with the user-driven approach of looking at how parenthood changes people’s way of living.

1.1 Background

Linear consumption patterns and resources use affects sustainability. If we humans continue living in the same way as we do today, a worst-case climate change scenario has been mapped out for this century, leading to an average temperature increase of more than 4°C compared to today. Such a temperature increase is expected to lead to more natural catastrophes and have a massive effect on this planet’s inhabitants and nature (IPCC, 2014). The index Representative Concentration Pathways (RCPs) represents the concentration of greenhouse gas emissions (GHG) and is described in the Fifth Assessment Report by IPCC. The worst-case scenario (RCP8.5 as mention earlier) is a ‘business as usual’, whereas the necessary scenario to reduce emissions is RCP2.6 which implicates a reduction of GHG by 70-95% in this century (IPCC, 2014; van Vuuren, et al., 2011). Industrialization has made some countries into highly developed countries during the last three hundred years, those countries are also the ones who pollutes and use resources the most (van Vuuren, et al., 2011). This structure is very complex to break out from, but the reason why it needs to be changed is that ‘business as usual’ will force the world into an Anthropocene era that probably is not sustainable for humans.

A stroller is one of the first product a parent or a close relative invests in for its newborn and is also one of the first products a newborn child comes in contact with. Parenthood probably change people’s previously life of living, for example in regards of convenience, such as the choice of commuting – by staying within the boundaries of transportation. Hence, the function ‘transportation of a child’ covers more than just the stroller as a transportation medium, rather the more holistic view which can include car, public transportation, bicycle, etc.

The stroller market is either from customers buying a new product, in a linear market model, or buying the product second-hand. The second-hand market is common since a stroller could be expensive but also holds a relative high quality, which makes it suitable to use longer than one use-phase (Blocket, 2011; 2013). This is something that potentially affects the stroller providers with the popularity of second-hand markets, which makes the exponential growth of business harder on a saturated market. The product itself has a relative short use-phase which enables it to be suitable for a more circular based business model. A circular business model makes the provider able to maintain control over the products life cycle and brings opportunities to use resources more efficiently.

1.2 Project Motivation

The figure below illustrates Earth’s climatic history over that last 800,000 years. The cycles follow a somewhat continuous pattern of high and low average concentration of CO2 in the atmosphere, that marks different ice ages. By examining the very far right in the figure, something odd has happened with the cycles - the previous peak of 300 CO2 parts per million (PPM) concentration is blown away by comparison to year 2015 when it reached 400 CO2 PPM concentration in the atmosphere. That is
according to Lindsey (2018) the same level of GHG as 3 million years ago, when the world had an average higher temperature of 2°-3°C and 15-25 meters higher see level above pre-industrial era.

As figure 1 also shows, the temperature somewhat follows the same path of the carbon dioxide movements, which indicates an average warmer climate. Global warming is a fact and with that, the nature changes its ability to provide for its inhabitants and natural catastrophes occur more frequently, which could be of immediately danger (IPCC, 2018). For every day humans do not change, this curve continues to reach new exponentially higher numbers and the more it grows – the greater actions it takes to get the concentration down to reasonable levels. One comparison level could be the pre-industrialization era, which is defined at year 1750 by the IPCC, where the atmospheric concentration (about 275 CO₂ PPM) was around 30% lower than of today’s levels.

Al Gore basically made the same point about this chart (figure 1) back in year 2006 when the concentration level was around 380 CO₂ PPM (NOAA; An Inconvenient Truth, 2006). One could always speculate about how this chart would have looked like if he became the president of the U.S. instead of George W. Bush. Comparing that with today’s level of 409 CO₂ PPM (NOAA, 2019) with how today’s president of the U.S. expresses himself on Twitter: “In the beautiful Midwest, windchill temperatures are reaching minus 60 degrees [Fahrenheit] . . . What the hell is going on with Global Waming [sic]? Please come back fast, we need you!” (Trump, 2019). This indicates that maybe political actions cannot be counted on and even if political actions are made, it does not necessarily mean that the inhabitants agree with those actions of fighting climate change.

This puts pressure on technology and humans to take responsibility. I am not saying that the role of a stroller will change the exponential path of the chart nor that it has a big impact in the first place. But it might give some insight on how design can identify and persuade consumable behavioral change and what technology and material that is necessary. This might also be applicable to other products that can be placed in a more sustainable system - every little step might help. That is enough motivation for me, as a product developer.
1.3 Research Aims and Questions

The overall research aim of this thesis is to: investigate the ecological-, economical- and social sustainability pros and cons of a ‘PSS Model Stroller’, i.e. using the stroller’s resources more efficiently by adapting it to a service model, in comparison with a ‘Conventional Stroller.’ To target this overall aim with the overall function of ‘transportation of a child’, these specific research questions (RQ) are addressed:

RQ1. What major aspects of the physical design of a PSS Model Stroller affects its life cycle to be in-line with the necessary environmental goals that IPCC has mapped out for the twenty-first century, in comparison to a Conventional Stroller?

To address RQ1, this thesis assesses what a Conventional Stroller is, by mapping its life cycle from cradle-to-grave. Then the thesis looks into opportunities to extend the amount of cycles a stroller can have, by changing its physical design together with an embedded service that brings a provider responsibility. This offers a base to compare this PSS Model Stroller to a Conventional Stroller. The physical design includes the product development, such as: product design, production, material and distribution, to after life, etc., which will be explained more in detail later in this report. To be in-line with IPCC environmental goals, scenario RCP2.6, as outlined in the Fifth IPCC Assessment Report (IPCC, 2014; 2018), means 70-95% GHG reduction in regard to the stroller development and use. This GHG reduction assessment is conducted by comparing the two system approaches to each other with a qualitative focus.

RQ2. What kind of PSS related services would potentially support stroller customers and users to take more ecologically-, economically-, and socially sustainable decisions?

Addressing RQ2 is done through focusing on providing services on a system level of the function: transportation of a child, in the scope of easing the users’ way of living, by providing a more sustainable option. The social awareness focuses on amplifying the user-centered values, which is assigned to the strollers’ system, while societal awareness has more of a human-centered augmented value approach on the connecting systems. It relays on creating services that provides enhancing values for the actors of interest in the use-phase that makes this stroller worth considering over another stroller.

RQ3. How can a PSS model stroller be realized to be more ecological-, economical- and social sustainable than Conventional Strollers?

Addressing RQ3 is focusing on a business model, which in this case means the packaging of this project, that includes the connections from the beginning to end of this system. A more intuitive way of getting a holistic overview of the project and its necessary actors, which makes it comparable to other business models. The business model should also mediate the result of the sustainable features of the stroller.

1.4 Limitations

The general mentality of what is going to be conducted, will be expressed in a way that makes it vivid for the readers to understand what the author wants to deliver. With that said, this is a design of a first mapping or pre-study and not a fully development of a product and its infrastructure. Thus, important features of this design needs to be illustrated and shown, which is expressed by prototypes, concepts and ideas.
1.4.1 Life Cycle
Due to the project’s timeframe, a full test pilot of the product’s life cycle is impossible. To be able to validate the life cycle, user feedback and interviews of the imaginary use-phase and interaction will instead be conducted. To measure the environmental impact of a Conventional Stroller, a simplified life cycle assessment (LCA) is done, also compared to already existing LCA studies of strollers. The main purpose of the physical design is to stretch its lifespan, while avoiding supplying excessive resources and energy when going from one user to another. The choice of mainly focusing on carbon dioxide (CO₂) of all the GHG that affects global warming is because CO₂ is the dominant emission in regards of product manufacturing, due to energy use in production and the use of virgin material.

1.4.2 Physical Prototype
The physical prototype includes the general elements of what makes a stroller a stroller, such as frame, wheels, carrycot, etc. That is essential, since the viewer has to understand what they are looking at, but the functionality such as folding it for transportation does not have to be working to answer the research questions. Other elements of importance are the elements and features that the research leads to in regards of PSS, product design, material and production, which has to be displayed in a convincing way but not necessarily functional. Detailed mechanical properties will not be calculated, such as strength of material and other mechanical engineering related characteristics. General assumptions and experience are considered good enough.

1.4.3 Platform and Interaction
The way of interacting within this PSS could be very large and therefore some kind of platform that is handling all this information has to be conceptualize. A platform, such as an application is an ongoing process with incremental added features in form of updates and new functionalities. It has a very high demand of developer implementing such a feature, which is not included in this project. However, the role of the platform in this project would be to “join the dots”, which could be illustrated with prototyping tools, such as images, flows, software’s, etc.

1.5 Deliverables
The information that is gathered during the research phase is applied on a physical prototype of a stroller. The prototype is a vessel of information that is conducted in this study, together with a platform that is expressed in a Service Blueprint and other visualizations, which illustrates the information flows and the interactions – will be the final deliverables together with this report. The project focus is in this case applied on the function transportation of a child including the physical product stroller and its connecting systems, but the knowledge contribution is also to investigate how to make product development more sustainable by learning more about eco engineering, product- and service design.

The definition of ‘child’ in this project is assigned to a child who uses and gets transported in a stroller, from newborn to toddlers, which are about the age of 0-4 years. The definition of ‘stroller’ in this paper includes the whole use phase, even though there are several different kinds of strollers in a use phase, this is simplified to just ‘stroller’ to include the whole life cycle of the function ‘transportation of a child’.
2 Methodology

The structure of this chapter begins with an overview of this projects’ Research Plan, then goes on with Insights Methods, which gathers material to conduct and create Concepts and Prototypes. Those concepts and prototypes need to be evaluated, which is described in Evaluation Methods, where further iteration is possible to be able to answer the Research Questions conducted by the Validation Methods.

2.1 Research Approach

This thesis work is done in collaboration with RISE Service Labs, to enable the mapping of the stroller users’ need, which is gathered by Service Design methods and tools. The tangible properties for a circular use-phase rely on PSS logics gathered by an Engineering framework of methods and tools. Costa, et al. (2016) express the differences of the two approaches that is used: “Values is defined as the result of a memorable service experience to consumers” in the discipline of Service Design, while “Value is defined in terms of value-in-use; focused in offering outputs (functions) while using natural resources more efficiently” in the discipline of PSS, which both will be incorporated in this thesis to fulfil the goal of a more sustainable stroller. To create value for the user, it is important to create this product through design thinking, which means that the stroller should reflect upon the users’ need and include a bottom-up structure that enhance the user experience.

This projects focus is on ecological sustainability, which means to achieve an improvement regarding environmental impact in comparison to a traditional product. Ecological-, economical- and social sustainability could be illustrated as a three-legged stool and if one leg brakes, the stool will fall, therefore all these components are equally important to achieve the goal of improved ecological sustainability. Thus, the user’s relation to the product has a human-centered approach that augment the experience beyond the actual product, that nudges the user to make sustainable decisions. Human-centered design is one level above user-centered design, which emphasis is on the user in a holistic and societal level, rather than direct interaction with the product (Meroni & Sangiorgi, 2016). Different kinds of approaches and technology are investigated to amplify the user experience, also a way for a stroller provider to maintain producer responsibility and continue to improve their R&D.

Through this multi-disciplinary approach; using design research with an engineering framework of a PSS, a subscription-based stroller is created. The product aims to aid the end-user to make sustainable actions. These two factors will be the foundation of illustrating a circular business model as an alternative to a linear business model. To conduct this information, several different stakeholder groups with a relation to a stroller is included in this study, such as parents and a stroller company.

2.2 Research Process

The research plan negotiates what this project delivers, what activities that are taking place and what kind of resources that is needed to fulfil it. This thesis topic is constructed by the author of this project, with inspiration from earlier studies in mechanical engineering, present studies in design with focus on sustainability and a specific course: ‘Advanced Ecodesign’, where the subjects of PSS, LCA and LCC was included.

The figure below illustrates this projects activity and path, where the different activity touchpoints varies of being general information of interest – such as things found in the methods, visualizations, tangible prototypes and concepts. Some of the activity touchpoints gives pieces of information to answering the research questions in the result chapters (chapter 3 and 5-7), which get displayed and concluded in chapter 4 and 8.
2.2.1 Activity

The activity of this report begins with the result chapter 3; Status Analysis, which includes: Two kinds of Business Models, Literature Study of different kinds of existing leasing or service business models, a Literature Review of Stroller Leasing, and Case Study – AngelCab of a stroller company, followed by a 4 Result Discussion – Status Analysis. These two chapters are addressed to gain information for answering the stated RQs and necessary theory is embedded in these chapters.

The following next three chapters 5 Service Design, 6 Product Design and 7 System Design are all results from the thesis process and considering the outcomes from previously chapters, addressing the RQs, which is discussed in 8 Concluding Discussion.

2.3 Insights Methods – Existing Knowledge

This section will give a deeper understanding of the initial project phase, describing the work path, which began with a literature study, followed by a case study of a stroller company, that leads to the finding potential stakeholders.

2.3.1 Literature Study

The literature study and its systematic approach of gathering information is inspired by Jesson, et al. (2011) who gives guidelines of where to search for information, categorize it, and how to review it. The information was accessed online through academic databases with peer-reviewed articles, books, some gray literature and through online websites.
The main purpose of a literature study according to Hart (1998) is to give understanding of the topic being discussed and strengthen the academic research result in comparison to the other studies outcomes. Hart (1998) also stresses the issue of narrowing down the topics of interest to make it manageable, hence the importance of tie the literature result to the RQs.

The initial phase of the literature study begins with a status analysis of detecting what kind of service providers within the stroller market that exists today, to get a sense of who their customers are and how their business model is constructed, i.e. addressing RQ1 and RQ2. Then the spectrum widens to other service provider companies regarding the topics of transportation and material flows, to still stay within relevance of a PSS stroller service. This status analysis aims to bring insights and inspiration, covering all three RQs, from platforms such as websites, company reports and news articles, i.e. gray literature, which can bring great value to the research outcomes (Haddaway & Bayliss, 2015).

To connect the above mentioned aspects to this thesis framework of PSS, an initial description of what PSS is, from an academic point of view is brought upon, as a step in-between going forward with a literature review about previously studies of strollers leasing grounded in the area of PSS (Hart, 1998). This is also a step of learning more of the three RQs that are addressed.

2.3.2 Case Study

The intent knowledge contribution from the Case Study is to get an empirical perspective of how a small stroller company works; what values they have, who the customers are and what their business model is. The five principles of service design thinking are followed; ‘it is’ user-centered, co-creative, sequencing, evidencing, and holistic, to gain the first insights of what to get inspired from, what to change, etc. (Stickdorn, 2019).

The case company in this case study is AngelCab, a stroller company from Germany, who profile themselves as a sustainable company in terms of material use. AngelCab has also made a stroller leasing study, which is relevant for this study, to get an empirical perspective in contrast to the literature study, to gain insights about their process (Yin, 1994). Doing a case study of a stroller company also provides valuable information about its structure and relationship with other actors. It also brings real data from this specific company and its design ideas, which is a valuable input for this project. The data that is collected is done through discussions concerning their products environmental impact, their customer, business approach, etc. (Creswell, 2003). The case study took place during one afternoon in the beginning of the research phase. From that base, this projects goals could be applied as an alternative business model and illustrate the results in a more realistic perspective. The structure of the physical meeting of this case study are found in Appendix 1 and was planned and coached by the supervisor from Linköping University and RISE Service Labs.

2.3.3 Analyzing Existing Knowledge

The insights that are gained from the literature- and case study are discussed and concluded in regards of the RQs stated and what stakeholders that might be of interest, in the chapter 4 Result Discussion – Literature- and Case Study, before going forward and designing this thesis outcomes of Service-, Product- and System Design.

2.4 Insight Methods – Forming New Knowledge

From the previously chapter new knowledge can be formed by applying design and engineering methods.
2.4.1 Statistical Analytics

The purpose of gathering statistic data is to strengthen the outcomes from the Insights Methods – Existing Knowledge. It is also a way to reach a broad stakeholder audience of stroller users, of how their everyday relationship to their stroller are. The statistical analysis is inspired by Day Reconstruction Method (DRM) (Kahneman, et al., 2004), which in this case is something in line with “Use-phase Reconstruction Method”, that covers demographics, income, brand of stroller, what features the users values, how the user use their strollers, how they bought it and what they plan to do after they are done using it, and so on. Hence, to get the user perspective, addressed by RQ2.

To get as much data as possible, the importance of reaching users in a convenient way is necessary. Hence, the use of Google (2019) online survey was selected, which collect and organize the data in manageable way, which facilitates analyzation. However, Nulty (2008) argues that there are drawbacks of doing online surveys compared to handing out paper for example, in regards of response rate. That is why it is important to base the questionnaires of the purpose of the thesis RQ, with the main purpose of gaining quantitative data that backs up the design decisions from a user perspective (regarding RQ2), where respondents also have the option of evolving their answers in free text (qualitative data). The used questionnaires can be found in appendix 7 (Creswell, 2003; van Boeijen, et al., 2017).

2.4.2 Interviews

The interviews are based on qualitative questions with a semi-structure interview technic with topics of interest that could be conducted from the specific stakeholder. Semi-structured interview aims to get a deeper understanding and let the conversation lead the pathway, while using some boundaries of pre-decided ‘themes’ or ‘guidelines’ (Kvale & Brinkman, 2014). Qualitative interviews focus on getting insights of how the stakeholder’s perception of their reality is and gain their perspective of the matter that is stated (Kvale & Brinkman, 2014).

The theme of the questions that are aimed for the customer/user detects how their thoughts concerns their stroller, how it affects them, how they look at their use phase, etc., which reflects over behaviors when making decisions about purchasing (i.e. addressed by RQ2). Another perception is to understand the stakeholder’s ability to accept a new disruptive way of using a product to determent thresholds and opportunities by letting the interviewee think and formulate their own theory regarding services (i.e. all RQs). All the interviews that are aimed at the customer/user group are made confidential i.e. the identity is kept anonymous of the ones that are being interviewed and have the pseudonym of ‘P#’ (Kvale & Brinkman, 2014).

In this study, two parents (P1 and P2) and one parent to be (P3) are interviewed and the interview guide is found in Appendix 3. To determine the relationship between private persons and organizations, such as daycare center for children, if an organization can have a central role in this projects business structure. Therefore, one responsible (P4) for a daycare center is interviewed, see Appendix 2 – interview guide.

2.4.3 User Personas

From the statistics and interviews insights, a user personas is created, which is an fictional generalization of a typical user who might suit this thesis PSS Model Stroller best, which is based on the previously research (Schneider & Stickdorn, 2019). The persona includes demographical information, relationship, value statement, occupation and technical abilities, to be able to create a scenario with a user in this PSS model. The user personas are also included in future evaluation, to work as a probe for placing it in the system.
2.4.4 Co-creation

Co-create or co-design is when the ‘Co’ is of importance and stands for collaboration, which is more of a service design philosophy rather than method or tool and can be practice with one or more persons of interest in the subject of matter (van Dijk, et al., 2019). Co-creation relays on using other methods or tools, but co-creation should be facilitated by someone who runs the project and could put up boundaries to steer the flow in the direction of interest, that person could be a service designer (van Dijk, et al., 2019 p.198-201). Holmlid, et al. (2015) emphasis that everything could be prototyped, and it is an iterative process of gaining insights, exploring concepts and developments, then narrowed down and specified to transform that information and apply it into the process.

The method that was used in this co-creation session with Peter Algurén was Desktop Walkthrough, which is a method using a small-scale model of a service environment and using different kind of props that could be moved around to act out different kinds of scenarios (van Dijk, et al., 2019). The material that was used, was a simple white large paper acting as an environment map, where different sub-environments was drawn, together with upraised paper props in different colors – representing different actors, stakeholders or objects. This gave the opportunity to explore the stroller as a service and also link it to other transportation services of his expertise to be able to answer the system or business model of this thesis (i.e. RQ3).

2.5 Evaluation Methods

The evaluation method consists of a Life Cycle Assessment (LCA) and a Life Cycle Costing (LCC) model, addressed in a planning phase to be able to evaluate different design decisions of ecological, social and economic sustainability actions, focusing on RQ1 and RQ3. Figure 3 includes step (2) Use-phase in the boundaries of the physical product, in which the stroller could be estimated to zero due to a stroll being a passive product (Kaebernick & Kara, 2003), but step (2) could have a large impact on all three sustainability categories, as discussed further in chapter 9.

2.5.1 Life Cycle Assessment

A simplified LCA is applied on a Conventional Stroller and the supposed PSS Model Stroller, for comparing those two masses \( M \) of carbon dioxide equivalent \( \text{CO}_2\text{e} \) impact to each other, in regards of answering RQ1 (Kaebernick & Kara, 2003). Simplified means to use a model that calculates inter alia \( \text{CO}_2\text{e} \) based on material input in relation to aggregated data for a specific material, from cradle-to-gate. The tool of the model is an Excel file developed for the course Resource Efficient Products - TKMJ129 by Linköping University (2019). To be able to assess a fully or true LCA, all considered data from every process has to be measured, compiled and calculated, which is data that is very hard to get hold of, if it even exists (Finnveden, et al., 2009). That is caused by the heritage from the industrialization and the capitalistic model that has not and do not, to a large extent consider or care about the emissions from production and the GHG effects from that is measured in a big chunk in the atmosphere instead.

There is four phases in the LCA: (i) Goal and Scope Definition – defining the system boundaries, level of detail and intent use, (ii) Life Cycle Inventory Analysis (LCI) – the input/output data within the system boundaries, (iii) Life Cycle Impact Assessment (LCIA) – the information about material and

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* A passive product is a product that does not use any energy during its use-phase. To compare it to an active product, which can be a car for example that uses energy in its use-phase to be able to work.

* Where \( M_{\text{CS}} \) is the mass for the Conventional Stroller and \( M_{\text{PSS}} \) is the mass for the PSS model stroller.
what impact it has on the environment, and (iv) **Interpretation** – which is the result of the three previously steps, which gets examined and compared to value the reasonableness (ISO, 2016).

The Goal and Scope Definition was defined to answering RQ1, which brings the boundary of cradle-to-gate (1), use-phase (2), refurbishment (3), n use-phase plus refurbishment (4), and End of Life (EoL) handling (5), illustrated in the figure down below.

![LCA Product System Boundary](image)

*Figure 3 illustrates an LCA for a physical product from cradle-to-grave.*

The product ‘Conventional Stroller’ has one guaranteed LCA scenario in a linear business model from the provider perspective which includes step (1) and (2), with some kind of step (5), see Eq.1.

(Eq1) \[ M_{Cs \text{ CO}_2 e (guaranteed)} = (1) + (2) + (5) \]

But the Conventional Stroller will likely be used by several customers before it reaches step (5), where the user actively has to decide what kind of EoL that would happen to the stroller. That scenario will look like Eq.2.

(Eq2) \[ M_{Cs \text{ CO}_2 e (likely)} = \frac{(1) + (2) + (5)}{n_{cs}} \]

The Conventional Stroller was then compared to the supposed PSS Model Stroller, which includes step (1) to (5) in the LCA (see Eq.3). The largest influence factor for change is step (4), which is linked to the product design of being durable, have low environmental impact and be modular constructed.

(Eq3) \[ M_{PSS \text{ CO}_2 e} = (1) + (2) + (3) + (4) + (5) \]

\[ \iff \]

\[ M_{PSS} = \frac{(1)+(2)+(3)}{n_{PSS}} + \frac{(2)+(3)}{n_{PSS}} + \frac{(5)}{n_{PSS}} \]

The system function within the **LCA Product System Boundary** for both Conventional Stroller and PSS Model Stroller is ‘transportation of a child’. The functional unit is to ‘transport a child throughout one use-phase for X years and be able to last for n use phases’. The reference flow in this stroller case is the ‘material used in the product’. All the real data is compiled in the result chapter 6.3.3 **Result from the Life Cycle Assessment**.

The LCI is conducted from a Conventional Stroller that is bought second-hand, the stroller model is a **Brio Smile**, which got disassembled and each specific material is calculated to measure its weight. The new supposed PSS Model Stroller is then designed to answer RQ1, which got modeled and constructed in a computer-aided design (CAD) tool, where the product design properties can be conducted. All this data could be found in Appendix 4 and 5.

The relevant LCIA data is included in the Excel-file and the aggregated material data is implemented from Eco Invent (2019), which is an online LCA material data base. Every material data is reviewed and compared to other LCA’s involving same material that is used in this process, to judge the legitimacy in the output result, for this system boundaries (see figure 3).
The interpretation of the result was compared between the Conventional Brio Stroller, the PSS Model Stroller and also on another LCA on a stroller made by Ang & Yifan (2012) that had similar properties as the Brio Smile. The result is then viewed in different kind of scenarios giving value to the variables in Eq1-Eq3 which generates different kind of outputs, see chapter 6.

2.5.2 Life Cycle Costing

There are three types of LCC: Conventional, Environmental and Societal LCC (Ciroth, et al., 2007). The first type is much like a calculation of estimating a direct cost assigned to a product or service, in direct material, i.e. unit cost, which often just look at cradle-to-gate from an economical perspective. While the second type, Environmental LCC, includes both economic and ecological aspects over the whole life cycle, i.e. cradle-to-grave. Societal LCC demands real money flows and should give an index score of the social value aspects related to the product or service over the life cycle, which works best as an evaluation in an already existing product or service, rather than when designing a concept (Ciroth, et al., 2007).

An Environmental LCC is applied on this supposed PSS Model Stroller, which includes the costs from the products life cycle from: supplier, producer, user, refurbishment and EoL, to address RQ3 (Ciroth, et al., 2007). Environmental LCC is based on the same scope, LCI and LCIA as the products LCA, where the purpose is to map the PSS Model Strollers costs and the environment impact related to the costs, origin from the ecological sustainability actions applied on the stroller, to be able to estimate a development cost on the physical unit.

Much like the LCA, this LCC works as a quick estimation tool, since both the LCA and LCC is done in the planning phase rather than an analysis phase of this development, which means lacking of real data and a generalizing approach is taken into action (Ciroth, et al., 2007). Unlike the LCA, the LCC is just a result discussion of something hypothetic, to give a sense or imagination of how the reality can look like, in regards of the whole system (i.e. RQ3)

2.6 Concepts and Prototypes

Prototypes is a way of life, which could be both physical and non-physical where the purpose is to act out a concept of an idea, which could be implemented in several levels of a design process, such as giving tactile and tangible feedback of scale and shape, work as a probe when conducting user experience, be a carrier of information for presentation and further development, etc. In a design thinking, iterative process, a prototype creates a simple space of a complicated idea for both the viewer and the creator, to be able to learn from by include the human factor of perception (Berglund & Leifer, 2013).

2.6.1 Physical Prototype

The Physical Prototype is created for several purposes, to be a tangible reference artefact of designing: product aesthetics, mechanics, material combinations, production walkthrough, scale and features, and be a user interaction and experience probe. The stroller prototype is mainly created to be a vessel of information to conduct RQ1 but was also the springboard to assign the other RQs.

The stroller prototype is a way of adopting the “provider goggles” to evaluate the different steps from material decision, production, to implement it in a market model, while balancing the sustainability actions of ecological-, economical- and social sustainability in a PSS business model. It is also a projection of the CAD model and the research conclusions regarding material led by the agile work method, that might end up as the finale hardware product, which for now, work as a physical evidence for RQ1 but also a tool in the following methods.
The PSS Model Stroller prototype is created in the Linköping University workshop, using some of the second hand Brio Smile stroller parts as building material, such as wheels, joints and connections, etc. The material and process that is used, are picked to simulate the supposed PSS Model Stroller as much as possible, some exceptions were done to keep prototype costs down, while simultaneous mediate a fair concept.

2.6.2 Service Blueprint

The Service Blueprint is a method that includes all service interactions that happens in a service system, including physical evidence, for example the physical prototype. The method is used to identify the user actions, front- and back-stage activity of the service provider (Shostack, 1982). The blueprint umbrella was detailed for step (2) to (5), if referring back to figure 3 and the Service Blueprint describes the concept of this market model as solution to RQ3. The Service Blueprint is a visualization tool to mediate the systems action taking place and can include several tools and as evidence (Schneider & Stickdorn, 2019).

One such a tool is Wireframe Prototype that is developed as a physical evidence to represent an online interaction platform between the provider and the user. A Wireframe Prototype is a “smart” collection of illustrated artboards that have functions assigned to different activators that gives feedback, such as a rapid prototype of a website or mobile application that a user can interact with (Becker & Berkemeyer, 2002). The purpose with the online interaction platform was to provide the user with pre-customer information, such as product and service discovery, costs, benefits, availability and so on to be able to evaluate the first user experience with the service.

The face-to-face interaction acts as ‘Service Hub’ and contains lines of interaction between the provider and user, which is included in the Service Blueprint. The Service Hub exist to provide a platform for product exchange, responsibility, support and refurbishment.

2.7 Validation Methods

The validation methods that are used to define if these projects outcomes answered the RQs was the decisions compiled in the LCA with belonging discussions in regards of RQ1 and decisions compiled in the LCC with belonging discussions in regards of RQ3. To validate the whole system, including RQ2, which concerns the user experience, the user has to experience the concept and prototype, i.e. a Service Prototype.

2.7.1 Service Prototype

To address the whole system including the product and service design of the PSS framework with a design thinking approach, the user has a central role of interact with it and give user feedback, which then works as validation for this systems feasibility. Service Prototype is a way of acting out the idea of this system, with the base of everything that has led up to the Physical Prototype, which works as a probe, and the Service Blueprint, which works as system scene with touchpoints (van Dijk, et al., 2019). Since the idea of a subscription-based stroller does not exists on the mature market, the need of a user that is suitable for a disruptive alternative is a good start to test the system, such a user could be a ‘lead user’, as a first step of validation (von Hippel, 1986). A lead user is a user likely to be an early adopter and also have the ability to influence the market, which also implicates the product or service.

To facilitate the service prototype with a user means to acting out the service scenario where a sort of role play takes place, i.e. let the user test out the concept of the service and reflect over the experience (van Dijk, et al., 2019). To be a facilitator and grasp the potential leads – filming the session could be an good option, which makes it that full focus can be directed at the participant (Creswell, 2003).
2.7.2 Customer Journey Map

A Customer Journey Map is a visualization of a customer’s user experience of a service (in this case the created user persona), showcasing the interaction with the service touchpoints that are taking place in service scenario (van Dijk, et al., 2019). The Customer Journey Map of the service blueprint scenarios is co-created with the lead user as a step in the validation process of the service prototype session. The information of finding the touchpoints of the Customers Journey is expressed in a visualization.
3 Status Analysis of Service Providers

3.1 Two kind of Business Models

To straighten out the different concepts of doing business, a discussion section - with embedded theory about linear and circular economy – is included. The purpose of this is to go from linear to circular when taking the position as a product and service provider, rather than just a product provider.

What is general throughout different product and service business models is that the provider eventually has to make a profit, to be able to sustain on the market. This section will mostly focus on the product and service roles in a financially system, rather than the economy, by describing Linear Economy and Circular Economy.

3.1.1 Linear Economy

Linear economy builds upon continuous growth, which this society generally represents (Geissdoerfer, et al., 2017). This relays on customers constantly consuming products and services, where the manufactured products have a negative impact on the environment, due to use of fossil resources uses. Due to the ambition of growth, lack of responsibility of knowing the path of the product is common, when the product is sold it has made some profit which means that two products could be produced and sold, and so it continues (simplified).

Since responsibility comes with costs, policies, system thinking and collaboration which many of the references brings up in section 3.1.2 PSS, the easiest and most profitable way of making money is to stay in the culture of take-make-use-dispose. This is an obsolete approach that Lebow (1955) expressed as: “... we make consumption our way of life, that we convert the buying and use of goods into rituals, ... we need things consumed, burned up, replaced and discarded at an ever-accelerating rate.” Since the 1970, humans have taken more resources than the Earth has been able to reproduce resources and that happens earlier and earlier every year (by looking at the worlds resources inventory on a yearly basis) (Stefansson, 2019). The financially structure of this is that money is made-up based on interest and potential, rather than actually tangible assets, which adds on to this capitalistic structure of constantly making more money.

The linear system is not all straight, someone’s dispose could become someone’s take, which extend the life of the product or resource, but this often happens in the path of down-cycling which may end up as creating heat or electricity from incineration of the product that now has become waste (resource for the incineration plant) (Ellen MacArthur Foundation, 2017).

3.1.2 Circular Economy

The report: The Limit of Growth by Meadows, et al. (1972) takes a direct stand against Lebow’s (1955) statement and was the first initiative of considering a new way of consumption goods. This later transformed into circular economy, that figure 4 illustrates, created by the Ellen MacArthur Foundation.

Figure 4 below mediates that the things we consume (the left side in the figure) should be biodegradable, i.e. stay within the planetary boundaries by using (“borrowing”) recourse provided by the biosphere. Rockström, et al. (2009) argues that the sectioning of ecological-, economical- and social/societal sustainability which the commonwealth has taken for granted in the Holocene, where resources are considered without limits, to constantly achieve economic growth to improve social aspects of wealth are now obsolete. In the Anthropocene, Earth is showing its protests of the
consequences of growth, which indicates that economy growth should be limited within society limits and society limits within the environment limits, i.e. staying within the planetary boundaries.

While the right side in the figure mediates a tweak of the industrialization heritage, i.e. being able to live a modern life with the use of fossil resources, products and services around us. But instead of being a customer we are users who have the product when we are in need of it, and afterwards it gets reused by another user (i.e. second-hand), maintained/prolonged/reused by a service provider or product manufacturer (i.e. PSS), or gets recycled to become something else (preferably of a material that does not lose quality nor demands to much energy). What is of major importance, is to have provider responsibility, to be able to prevent the clause in the bottom of the figure of leakage as much as possible. The leakage is impossible to totally prevent, which is why critic exists against circular economy and cradle-to-cradle (Bakker, et al., 2010), because it is not literary ‘circular’. But in contrast, linear economy and circular economy could be explained with algebra: where the function unit is equal to resources and the limit value goes towards infinitive in the case of linear economy, and the ambition of the limit goes towards zero in the case of circular economy and as stated before, resources are not endless.

Figure 4 is the infographic ‘Butterfly diagram’ developed by the Ellen Mac Arthur Foundation (2017), which describes their take on circular economy, with the renewable flow management and the stock management.

\[ \lim_{x \to \infty} f(x) = \text{Linear Economy} \quad \text{and} \quad \lim_{x \to 0} f(x) = \text{Circular Economy} \]
Bakker, et al. (2014) wrote a book about how to make ‘Products that Last’, with the same title, which can give opportunities for a circular economy. They describe five kinds of business models: (I) The Classic Long-Life Model, is usually products with very high quality, often found in the linear market model were the price is rather expensive if comparing to similar products in the same product category. Therefor the customers expect to be able to maintain these kinds of products and perhaps with a good customer service as well. (II) The Hybrid Model builds upon a good quality base with interchangeable consumables, such as printers and razorbaldes (III) The Gap Exploiter Model can perhaps be assigned to the creative ones, who uses what might other consider as waste and creates something new out of it, which is something that is becoming more popular, such as reclaimed wood, repair cafés etc. (IV) The Access Model is the ultimate short-use product leasing service, with companies as Void. And (V) The Performance Model is a pure service experience, where the user buys the function of something, which could be food delivery for example.

Bakker, et al. (2014) also brings up a few principles to have in mind when designing for circularity: (i) Design for Attachment and Trust is important to gain recognition in the first place and to give the product a ‘want factor’. (ii) Design for Durability emphasis on high quality of the functions but also the style should last for the predicted future of use. (iii) Design for Standardization and Compatibility, which ease the process of using parts that are made according to the ISO standard for example, to knowing that the parts of standard are available and follows a laws and legislations. (iv) Design for ease of Maintenance and Repair is the foundation of being able to prolong the products life cycle, where (iii) could fulfill some of that criteria. (v) Design for Adaptability and Upgradeability is especially important for a long-term product, to be able to adopt it to new technology and style to fulfill the users need. (vi) Design for Dis- and Reassembly could be of importance when sending items, to have knock-down design.

### 3.2 Literature Study

The status analysis covers service providers in regards of child care and a general analyze of PSS.

#### 3.2.1 Child Care Related Services

There are a few companies that provides a business-to-customers (b2c) market model where the service function of transportation of a child with the purpose of easing the situation when traveling with kids, they do not only offer strollers, but also other baby utilities that takes a lot of space when traveling. These companies are usual based in a specific city, such as London, Amsterdam or Barcelona – companies such as Air tots, Travel Baby Amsterdam and Easy Travel Kids.

The service provides delivery of the ordered things to the users travel address, or the user could pick it up at the airport upon arrival. The user has to be careful with the things they are renting, just like you have to be when renting a car, which means that the user also has to pay a fee if they brake or scratch things (Air tots; Travel Baby Amsterdam; Easy Travel Kids, 2019). This solution is therefore aimed for customers who are on vacation, rather than an everyday situation, which is a quite common business model that exist in several places in the world.

Something that exist for longer term rental or subscriptions is for example a car seat, i.e. the part that the babies and older children are placed in to fulfill the safety requirements in a car. In Sweden there is an organization for roadworthiness that provides this product and also upgrades the car seat as the child grows (NTF, 2019). This is something that also lays in the interests of insurance companies, for example the Swedish insurance company if... they provide an add-on insurance for child insurance, which is a monthly payment that includes upgrades of the car seat as the child grows (If Skadeförsäkring AB, 2019a). The reason why this subscription-based model is feasible is due to the safety demands that applies to car seats (Bilsäkerhet; BeSafe, 2019), that includes laws and
regulations, which is best provided through standardizations. The standardization for car seats is called ISOFIX, or more correctly ISO 13216-1:1999 (2014) and contains standardization of a universal system of anchoring a child car seat in vehicles, which most of the modern cars is also adapted to, such as Volvo cars (Volvo Cars, 2019; If Skadeförsäkring AB, 2019b).

3.2.2 Product Service System

PSS aims to make physical products/product development more resource-efficient by adopting it to a circular economy business model (Tukker, 2013). This is gaining a lot of interest in business-to-business (b2b) side of industry, since the attribute of a product is just function and nothing more, compared to how a private person can feel towards a product regarding aesthetics, affective values, etc. It also suits well with the economical sustainability approach of not owning and spreading out the cost on a full calendar year, rather than direct purchasing. Lindahl, et al. (2013) describes several successful b2b cases in a review, such as a compactor machine that is designed to be easily repaired by the user or service provider that has the machine on a leasing basis and when the customer ends the lease, the owner company of the compactor can easily refurbish the machine by changing some cosmetic parts to make it have a new standard.

It is important to make these functional sales environmentally and economically beneficial, where much of that design’s origins back to the product design of being easy to: maintain, clean, be modular, have standard parts, etc. But also have the infrastructure, human structure and organization layout in order to make everything feasible, in that sense it is a big system that has to be develop in order to adapt to a PSS business model (Sundin & Bras, 2004 ; Rondini, et al., 2016 ; Mont, 2001). However, concerns have been raised by Stål & Corvellec (2017) about the risks that can occur with PSS, such as more material use when refurbish, unsustainable transportations and the potential rebound effects that enables when having more money to spend on other things (hence spreading out the costs).

To address these risks, the perhaps previously product provider has to change their approach to become a service provider throughout the whole life cycle, with the ambition of creating customer value to the above mention regarding an ecological sustainable product design but more importantly create value with services (Matschewsky, et al., 2018). This is where the discipline or competence of Service Design plays a vital role, where Costa, et al. (2016) emphasis on the importance of a co-driven user approach, to create service user value that closes the gap of ‘not owning’ the product by creating a great service experience instead.

3.3 Literature Review of Stroller Leasing

The following subheadings will mediate the result of the literature review of papers that have studied ‘leasing of strollers’ with the purpose of detecting what needs to be achieved for a PSS business model. The cases include two stroller companies, ‘a leading stroller company in Sweden’ – which for simplicity from here and on will be called ‘Annaboda’, and ‘Bugaboo’. Both Annaboda and Bugaboo are considered premium brand and their strollers both starts around €1.000 (Mont, et al., 2006; Sumter, et al., 2018).

3.3.1 Introduction

This review manly focused on three papers: (i) A new business model for baby prams based on leasing and product remanufacturing by Mont, et al. (2006) covering Annaboda, (ii) ResCoM – transforming waste into high value resource through closed-loop product systems by van Loon & Van Wassenhove (2014) and (iii) The Role of Product Design in Creating Circular Business Models: A Case Study on the Lease and Refurbishment of Baby Strollers by Sumter, et al. (2018) covering Bugaboo. Another paper that also is frequently referred to, is: What is Mine is not Yours: Further Insight on what Access-Based Consumption says about Consumers by Catulli, et al. (2013), which brings up social aspects about using
“not new’ or ‘refurbish products’ within the product category ‘baby and nursery equipment’ (including strollers) – that is an interview study with a total of 26 women and 4 men, in the age ranging from 22 to 38, with mixed ethnic background.

3.3.2 Research Incitement of a Stroller Leasing Business Model

In the year 2000 there was a two-year case study of the company Annaboda, that investigated the cost scheme of using a PSS approach of leasing strollers, the study was made by Mont, et al. (2006). The reason behind the study was that the stroller company felt the saturation of the second-hand market, which they estimated to be around 65-70% of the market. Hence the declining of the company’s growth, origin from high prices of new stroller – while ‘good quality’ stroller easily could be found on the second-hand market for the potential customer. The predicted outcome from the study was that a leasing stroller (prams) could at least be in the loop for 4 years with 8 users, which implicates the leasing period to 6 months. The cost calculation showed that it will take 12 months until the company starts making money on the stroller, which means that there will be a negative cash flow in the beginning, which could somewhat be covered by the customer paying a deposit in the begging but will of course not be in the same levels as the negative cash flow. The three remaining years would be beneficial with a positive cash flow, even more than just selling it as a conventional stroller and also has the potential of selling it as a second-hand stroller after the leasing period ends.

Bugaboo is a Dutch stroller company that was founded in 1994, which got known for their modular strollers that could adapt to change and their details to high-quality, which has made them into one of most popular brands on the western stroller market in the higher price segment (Sumter, et al., 2018). Due to their impact on the market, they have become a valuable asset for researchers to investigate sustainable and circular economy business models, such as in the EU program: Horizon 2020, FP7 which inter alia finance the project Resource Conservative Manufacturing (ResCoM), who is the initiator of investigated Bugaboos ability to create a closed-looped system (European Commission, 2016; ResCoM, 2019). Bugaboo did also do an own leasing study called: Flex Plan, which has been followed up by several research institution, such as Lund and Delft University and is also included in ResCoMs study (Sumter, et al.; Bocken, et al., 2018; Bugaboo; ResCoM, 2019).

The ResCoM project written by van Loon & Van Wassenhove (2014) investigates if a stroller could adapt to PSS and a circular business model, which factors of a stroller that is suitable/unsuitable as a closed-loop product – displayed in a design structure matrix, conducted by a case study of Bugaboo and literature review. The ResCoM goal is to present a system that is “…cost-efficient, resource-efficient and more sustainable than current linear manufacturing system…” (van Loon & Van Wassenhove, 2014, p.5). While Bugaboo, much like Annaboda, are concerned about the saturation of the second-hand market and also strives to becoming more sustainable. The report lifts the pros and cons of adopting to a closed-loop system, where the stroller users has an emotional attachment to the product and put the most value on safety and quality, but also aesthetics, hygienics and costs. Hence the market for both new and second-hand strollers, where the stroller customer invest a lot of time and research, such as online forums before purchasing (van Loon & Van Wassenhove, 2014).

Looking at the ones who are supposed to use this service of leasing, there seems to be a mixed set of reactions from the ones being interviewed in the Catulli, et al. (2013, p.200; p.202) study: “I’d feel good that I was doing something good for the world, not just putting something into landfill or buying something for the sake of it”; “Yeah, so having a sort of ‘If you do this, you are saving this much resource’, it would interest me …” or “The idea is repugnant to me because I think it conjures up to me ideas of being not clean, over-used, possibly faulty, exposing my child to things I don’t know about, germs etc. I feel like a loss of control at a time when I would want to have a lot of control over the environment my child was in and the equipment that was being used.”
3.3.3 Applied Product Design of a Stroller Leasing

The product quality of each new use-phase should hold the standard ‘as new’, which puts high demand on the repair and refurbishment, the suggested solution that Mont, et al. (2006) investigated was to do the repairs out in the country, i.e. at the retailers. Not every part of the stroller would be suitable for refurbishment and repair, where the textiles and padding were seen as the most critical objects, which would be swapped out to achieve that standard ‘as new’, while the chassis and frame, if not damage, could serve several cycles and wheels would be suitable for changing every other year (Mont, et al., 2006). This is also something that concerns the users, that the stroller would not be safe enough when being refurbished, the ability to trust the producer of guaranteeing the necessary standard of safety and especially being concerned about the hygienics the fabrics (Catulli, et al., 2013).

Even though a stroller from Bugaboo last longer than one use-phase (one use-phase equals approximately three years), there are customers demanding brand-new strollers, which is introduced every three years with an updated design, which is in line with linear economy and affect the environment in a bad way, due to consumption of resources (Catulli, et al., 2013; van Loon & Van Wassenhove, 2014). The Bugaboo Flex Plan did some modifications to their product design, such as conducting the importance of standard modules between product generations, to be able to replace certain parts when going from one user to another (Sumter, et al., 2018). That leasing study was built upon three use phases, where the last user kept the stroller, since the frame of the stroller was calculated to last for three life cycles (Sumter, et al., 2018). The reality however, showed an uncaring mentality by the users, that one third of the frames was weary out already after one use phase, due to scratches and buckles and needed to be replaced, the plastic wheels did also have to be refurbished and treated after every cycle, while the carrycot with belonging fabric already was pre-decided to be replaced after every use-phase (Sumter, et al., 2018). This indicates worse environmental impact than a conventional stroller, due to lack of adapted product design for a leasing stroller. The issue of the user breaking the stroller is something Catulli, et al. (2013) also discovering when interviewed people of interest, not owning the product makes the user insecure when acting with children and perhaps older children in the family being unpredicting, which also could destroy things on the stroller.

The aesthetics of the product design relates to the product brand, something that both Annaboda and Bugaboo sees as a concern when considering of implementing in their strollers in a leasing business model. To avoid destroying the image of the brand, a daughter company was in consideration, where they could allocate the resources for refurbish and bring in their second-hand strollers to that company instead, which would dislocate the associations with their premium brand (Mont, et al., 2006; Sumter, et al., 2018). These concerns is something that the stroller user also could identify themselves with: “...felt good about being seen using a fashionable, top of the range product...” and “…if you’ve got a Bugaboo which is obviously, you know, people want them, because they’re really expensive...” (Catulli, et al., 2013, p.199).

3.3.4 New Logistics that occurs when Leasing Strollers

There is a lot of changes going from a linear to a circular business model in regards of the stroller company, resellers and users. The Sumter, et al. (2018) paper concludes that there are confusions within Bugaboos design and management employees of what design competences that are needed and the way of acting when designing for a leasing infrastructure, such as Bugaboos own study: Flex Plan. The main conclusion from the Flex Plan was that Bugaboo employee was not organized to be a company providing a service instead of selling a products, the uncaring of the users that could destroy the premium brand, not enough adopted product design and hard logistic management (Sumter, et al., 2018). While a study from Lund University found that retailers were positive for a leasing business model, to win market from the second-hand market (Bocken, et al., 2018, p.16), which the other studies indicated as a risk, since the resellers would not earn as much money on it and perhaps be the
one taking responsibility for refurbish the strollers, compared to selling it in a linear market model (Mont, et al., 2006; van Loon & Van Wassenhove, 2014; Sumter, et al., 2018). One direct logistic hazard that was discover with the Flex Plan that had big disadvantage on the eco-impact, was that the subscribers often wanted to change the aesthetics of their strollers, by changing the fabrics look, which lead to more produced fabric and more deliveries (Sumter, et al., 2018). This was a service that was provided to make this business model more attractive and to convince customers to adapt it.

The ResCoM report stresses the importance of IT/Technology system connected to the stroller – such as: product traceability, configuration management, failure recording and analysis system, but also embed things like contract, product configuration and communication platform between the user and the company (van Loon & Van Wassenhove, 2014). This has an impact to be able to fulfil a closed-looped system, where the monitoring of the products parts health could be traced and therefor plan a structure for maintenance and part swaps, which then gives opportunities for a reversed supply chain and the ability to remain producer responsibility (van Loon & Van Wassenhove, 2014). The traceability is something that could give trust to the leasing consumer as well, Catulli, et al. (2013) detected that some user felt uneasiness about not knowing the history of the stroller, which is why this feature could be implemented for the users, in a platform service.

3.3.5 Environmental Impact of Leasing Strollers

The environmental impact was not calculated in the Annaboda study, since that demands a fundamental LCA study and trustworthy data, which could not be provided from the company or their suppliers. But the authors of the article argued for the potential benefits that the producer could make with this kind of business model, such as keeping the responsibility of recycling or remanufacture of the material, which could achieve a more environmentally friendly business model than a traditional (Mont, et al., 2006). There is also a risk of more transportation emissions due to the increasing deliveries and pick-up that will affect with a leasing business model. Also, if the user has to go to a retailer for pick-up and drop-off, while simultaneously having lower cost (paying less by month, rather than everything at one time purchase), a possibility is that the user will buy other things at the retailer, which thus increases the consumption level even more. This theoretical study was supposed to be tested in reality, but due to management changes within Annaboda, it never got implemented in a test study.

The precise environmental impact of a stroller is hard to conduct since trustworthy data is hard to access, but Bugaaboos strollers are manufactured in Asia and the biggest impact occur in manufacturing and shipping phase, since it is a passive product (Sumter, et al., 2018). The ResCoM report stresses that there is a lack of public publications of LCA mappings of strollers, which is true, which made the ResCoM group do an own LCA study, that also is not public, which is the same situation with the Sumter, et al. (2018) study. The result agrees to the previously stated assumption that the largest environmental impact occurs in the manufacturing state and also mentions the one public LCA that is available, made by Ang & Yifan (2012), which resulted with one strollers’ impact is 321 kgCO₂e form cradle-to-grave with a business-to-consumer approach. The study was made on a bestselling stroller, which could be likened with Bugaabo and Annaboda, with the assumption of end-of-life ending up as landfill, since a linear business model cannot guarantee producer and/or consumer responsibility for the end-of-life handling leads to recycling (Ang & Yifan, 2012). The authors of that study stresses that the input data in the LCA follows the requirements of PAS 2050 but is also based on secondary data which could be more correct if direct data was available (Ang & Yifan, 2012).

Even though ResCoMs LCA is not public, their conclusion is that the frame made out of aluminum and the hinges made out of glass-fiber reinforced nylon are the parts with the most environmental impact, but it is also the most durable for reuse for several use cycles (ResCoM, 2019). Several use cycles are the main research purpose with the ResCoM report and to be able to create a more sustainable
product, every resource need to be optimally used (ResCoM, 2019). Therefore are a PSS with a circular economy business model, where the consumer pays a monthly subscription fee a way of designing out resource losses. That also Catulli, et al. (2013) study indicates, that traditional owned strollers have a risk of being stored after its use-phase ends, of reasons such as the value is too low to sell on the second-hand market or it might come another child that could use it, etc.

3.4 Case Study – AngelCab

This case study was made at AngelCabs concept store in Berlin on the 21st of February, with one of the co-founders of AngelCab – Vinzent Karger. The following result will be summarized below and are based on the questions found in Appendix 1 and was audio recorded from that case study interview with Karger (2019). The image below is taken during the case study at AngelCabs store.

![AngelCab image](image-url)

Figure 5 is a picture taken at AngelCabs store in Berlin.

3.4.1 Sustainability Actions

According to Karger (2019) there was a lack of sustainable strollers on the market back in 2014 when he and his brother started the company, which motivated them to start the company AngelCab, due to the recent environment awareness among people. Their approach is still today more unique compared to other stroller companies in Europe. Karger (2019) argues that the big companies on the European market uses a mass production method where they are using a lot of plastic and synthetic
material throughout their stroller design, where they make many parts monolithic in plastic blocks, which makes it harder to repair if something brakes. AngelCab are not flawless either, they have some plastic material on their strollers, much of it found in the joints and connections, but also some parts in the carrycot. He states that it is possible to use more environmentally friendly material, but that also drives up the cost much more, which makes it harder for customers to pay for the strollers. One example of material differential is AngelCabs carrycots, some of the chassis are made out of wood, they use coconut fiber in their padding and the seatbelt is made out of ecological cotton rather than synthetics. Other parts of the stroller, such as wheels are made out of aluminum instead of plastic, but it is the quality that makes the biggest difference, every part and screws are basically replaceable.

3.4.2 Business Model

AngelCab identify themselves as a sustainable company, which they highly likely are since they are choosing their material carefully and the physical design is very interchangeable down to its smallest parts. But they do sell their products in a linear business model, which they have investigated to change from. That study included 20 strollers for 18 months, where they sold a stroller to a fixed price (like regular) and then bought it back to a fixed price with the possibility to do some discount on their payback by analyzing some parts.

The outcome from that study was that the strollers was more tired up compared with a stroller used by a regular customer, where the most obvious damage was made on the metal frame with substantial scratches. The conclusion from that was that the customer did not care as much since they knew that they were going to get that pre-decided, fixed price, more or less, back when they returned the stroller to AngelCab, which also was higher than if the customer was going to sell it themselves on the second-hand market. The other issue that affected their business model, was that they now had a product that was refurbished compared to their other new products and still has the mentality of good customer service where they can replace broken parts to fulfill customer’s satisfaction.

This created a situation where a customer could buy a cheaper refurbished stroller and then replace parts provided from AngelCab for free, for AngelCab not to destroy its reputation. From an ecological sustainability angle, this was a good approach, but form a company economic standpoint this was not sustainable, add to that the new logistics and repair costs, made them not continue with this business model.

3.4.3 Production

Due to the careful way of choosing material and whom to collaborate with, manufacturing costs have been increased. Karger (2019) argues that their products are in the higher price range, compatible with brands such as Bugaboo and Emmaljunga, but they don’t have as large profit margins as they have, actually only one-third of the profit compared with their competitors. This is because the competitors, such as Bugaboo and Emmaljunga, have a large-scale production in Asia and Poland, which keeps the price down and AngelCab has also more expensive input material in comparison.

AngelCab assemble their strollers in Germany and work with some local manufacturing companies close to their assembly-line in Nürnberg. They also use other productions facilities outside the country, such as the plastics and aluminum parts are manufactured in Poland, which is also the most difficult area to reach high environmental sustainability. AngelCab is too small of an actor to change the industry and demand recycled aluminum for example, which is something that origins back to structure and even political regulation, it is too cheap to manufacture out of virgin material which is not resource efficient.

Fabric is a large part of a stroller and also a very critical material for the environment. Therefore, AngelCab collaborate and use the Danish producer Kvadrat as their fabric supplier. Kvadrat is known
for their sustainability actions and are one of the leading driving forces of making fabric more sustainable (kvadrat, 2019). The fabrics purpose is to create a comfortable surrounding for the child, protect it from weather components and it is also a design element that changes along with fashion trends. Karger (2019) believes that the refurbished/second-hand fabric would face the largest resistance among stroller users, since it has a risk of getting worn-out, the feeling of being unhygienic and the fabric is also sensitive for fashion trends.

AngelCab does not know exactly how their environment footprint in numbers are, they cannot get all the data from suppliers to be able run a reliable LCA, they also lack that kind of competence in-house to run an LCA. They do however believe that that the quality, being locally attended and the choice of material are convincing enough for them to classify themselves as a more sustainable option.

3.4.4 Products

The figure below shows AngelCabs two stroller models, Classic (top-left) and Urban (top-center). AngelCab has two carrycots, the laying carrycot that is mounted at the classic stroller, which is amid for the youngest children (0-12 months) and then the flexible carrycot which is mounted on the urban stroller in the figure. The flexible carrycot can adjust its back support from 178°-90° angle and could be used throughout the whole stroller use-phase (0-4 years). In the figure there is also a carrycot that is a car seat (down-center) – for safety when traveling in cars, which is illustrated in the right of the figure. The car seat is not AngelCabs own product, but they offer it with their mounting fixtures that makes it possible to mount it on their stroller models. As the arrows in the figure illustrates, the freedom of choosing chassis/frame with the desired carrycot is possible, the laying carrycot even provides the added value of mounting it as a childbed.

Figure 6 shows AngelCabs products.

The car seat is optimized for traveling in cars and has a lot of regulations and demands assigned to it. For a stroller company as AngelCab there is not profitable to try to take that market, mainly due to the safety requirements, which implicates if something wrong happens, it would have devastating consequences – which brings a risk of destroying the whole company. Since the carrycot car seat is optimized for traveling in cars, the situation to use it both as an everyday carrycot and a car seat is possible but not desirable. The car seat is more safe than comfortable, it is quite clumsy, not very stylish and not very sustainable, due to the amount of plastics and chemicals that it has to have to fulfil the safety requirements according to Karger (2019). The car seat is therefore a necessary supplement
if the user has a car – to provide a safe ride for the child. The car seat that AngelCab provides also comes with the standard ISOFIX, which gives a seamless experience when moving between stroller and car.

3.4.5 Customers

Much of their branding relies on customer recommendations and AngelCab also shares content from them and customers on social platforms to influence new potential customers. AngelCab’s customers are only private individuals, they have no organizations or kindergarten related collaboration. In the beginning, when they started the company, their customers were mainly highly educated people that cares for sustainability and are aware of environmental impacts. As time went by and popularity around AngelCabs brand grew, other types of customers got attracted to their products, since the AngelCab stroller are in the higher price segment, makes it attractive for rich people, the ones that just see the environmental sustainability as a good extra feature, but it was not the main purpose why they went for a AngelCab stroller – rather the look of it and the customer support they got.

As mention earlier, AngelCab rely on delivering a quality product and good customer support, which then brings in new customers due to good reputation. AngelCab does of course want to hold on to the ones who bought a stroller from them – for AngelCab to offer other products for the customers to buy. One channel AngelCab does that through, is that they let the customer add data of when they purchase the product, for AngelCab to be able to send out email of maintenance, which makes the stroller hold for longer, but also creates a forum to showcase their new products in the right moment, as other companies also does.

AngelCab do not use resellers because they take to high margin which is not economical sustainable for AngelCab since they have quite low margins already. Hence, the two concept stores, which is a modern approach that also Tesla uses for example, which enhances the relationship with their customers. That relationship works as quick way of receiving customer feedback, which then provides possibilities to change lacking design.
4 Result Discussion – Status Analysis

4.1 Major aspects that affects the physical design of a PSS Model Stroller

The most outstanding concerns of leasing a refurbished stroller is that the product will not fulfill as good standard that the customer/user demands in regards of hygienics and safety. Both Annaboda and Bugaboo’s solution to that was to exchange the parts that contains fabric, i.e. the carrycot, in-between every use-phase. This could probably lead to an increased environmental impact, due to the unsustainable material resource use in fabric production (Schor, 2015), but also the different treatment processes of chemicals that is applied to fabric in-use of child products, due to legislations, such as inflammable- and wheatear resistant impregnation (Karger, 2019). This is in-line with Stål & Corvellec (2017) concerns about an unsustainable approach of resource use that PSS might lead to and should therefore, at least take the circular path of the bio-sphere (Ellen Mac Arthur Fundation, 2017).

Another backlash of leasing that occurred in these cases was that the users did not treat the strollers as careful that they probably would have done if they own the product themselves and had to sell it after they were done using it. This is a concern that the provider probably has to accept and therefore adopt the product design to that scenario instead, which was underestimated, since neither Annaboda, Bugaboo or AngelCabs solution did not change the product design any significant for this business model. However, Bugaboo did some improvement of generalizing the parts standard over product generations and AngelCabs already have that in their design, which improves the ability to provide a modular system that is adaptable and back-compatible over time, which is something to take inspiration from and add the concern of making does modular parts low on environmental impact. This is also something that is in-line with the PSS suggestions (Rondini, et al., 2016).

When comparing AngelCabs to Annaboda and Bugaboo, their stroller design seems more suitable for a PSS business model, due to the reparable of the parts and how they are jointed together. Yet, they approached their study of leasing out the strollers in a wrong way, since they failed in terms of economical sustainability for themselves, while it probably was very ecological sustainable, where the material was used extendedly, if it not was too damaged. AngelCabs also seems to choose their material with another preference than just make as much profit as possible in regards of choice of fabric for example. This might do AngelCabs to one of the most ecological sustainable stroller companies in the linear market, where they use premium material. They are in the upper price segment, which probably has reached its limits of what customers are willing to pay, and therefore do AngelCabs earn less since they are paying more for the material and production.

4.2 PSS related services that support the customer and user to take more ecologically-, economically-, and socially sustainable decisions

In the AngelCabs case they probably had “too excellent” customer service, which made the user experience excellent and that drove the brand identity to high satisfaction and attracted people that cares for the environment, which is a good way of marketing, when they did their leasing study. That approach did not work out financially for AngelCabs, which is why they did not implement their pilot leasing study, but they still kept their customer care support which is more suitable for a linear market model. They now claim to have reached other types of people, i.e. people that like the look and feel of...
the strollers and does not necessary care that much about sustainability, which is a good thing, if the agenda of ecological sustainability still exists from the company.

To make this into a sustaining business model, the importance of the provided services has to be a pull-factor that gives the users something more than if they bought a stroller. The risks of making the services a pull-factor is that it could increase consumption due to lower monthly payment which gives the users more room to spend their assets on something else, i.e. rebound effect. Hence the scope and the purpose (of being sustainable) of the business model has to be clear for the users, which in itself could be a pull-factor that makes the users feel good about their choice. The opposite seemed to happen to Bugaboos Flex Plan, where the users swapped the carrycot due to new impulses of changing the style of their stroller.

From a user perspective, the financial aspect has to either be more affordable or it has to include more provided benefits in regards of services to convince them to choose leasing over owning. These two companies did not take any user centered approach, more than providing the service of EoL handling, which is probably why this attempt failed on both being an improvement of user satisfaction and being more ecological sustainable. Therefor the question of what would ease the users’ life in regards of transportation of a child has to be addressed, to turn this framework into something sustainable.

4.3 How a PSS model stroller can be realized to be more ecological-, economical- and social sustainable than Conventional Strollers

From a provider perspective the second-hand market creates saturation, which is a first indication of providing a PSS business model to close economical losses. The undesirable aspect is that it will be a negative cashflow in the beginning that the provider has to account for. In Annaboda and Bugaboos case, the solution to that was to take a deposit from the users, which might indicate an unpleasant user experience. An option for the provider instead of a deposit could be to take a loan or create a credit company allocated from the regular business. In Annaboda and Bugaboos case, who are two established companies, they could follow Cristensen (2013) advice of creating a daughter company, where money could be allocated to run the business, to smoothly enter the market. This could also prevent harming the premium brand of Annaboda and Bugabo which was a concern, and slowly enter the market, even if it takes profit from the ‘regular’ brand.

Mont, et al. (2006) suggested that the repairs and refurbishment should be done out in the country, at the retailers. This will stimulate the employment market and open up for new opportunities of providing a service to the users. Regarding the material and production, this should also take on this locally attendance of bringing value to the region and also take advantage of the environmental benefits that comes with staying locally. One could argue that much has happened since 2006, when Mont, et al. did this investigation, such as the increase of online shopping and other business forms. This is why other types of modern opportunities could be implemented if doing this from scratch, such as providing a more flexible service of refurbishment without the need of retailers which could exist where the users exists. To bring in a layer of social sustainability to that, one idea could be to hire people that has a hard time finding a job, which could be provided by the municipality or label market foundlings (Statens Offentliga Utredningar, 2019).

AngelCab shows, in this stage of age that they can sustain a business where they make high quality products that are more sustainable, but due to that cause have less profit. That might be an alternative way of ecological sustainability improvement but does not attract and inspire the big crowd of making business. It is also hard to judge how good they actually are for the environment, since they do not have any life cycle data and they only use virgin material.
AngelCab do not use resellers, which is a way of maintaining control over the customer care, they do reach the world by selling strollers online, which they backup with an inspiring Instagram account of nice pictures and stories. They also ask for the users contact information and the age of the child to be able to provide customer care information of maintenance of the stroller but also marketing new products or upgrades in the pattern of the child’s growth.

4.4 Outcome Conclusions form the Status Analysis for further investigation

This section will concretize the discussion above and bring up the main pieces that might lead to a more sustainable PSS business model regarding Service-, Product- and System Design. Note the order of design approaches, where future chapters will first capture the user need with a finding of ‘user value’ approach, then create a product design and lastly combine services and product design into system design, i.e. a business model.

4.4.1 Concerned Stakeholder from a Linear Business Model

The figure below represents the linear way of doing business that occurs for example with AngelCab. With a material supplier that gives opportunities for AngelCab to create and sell a product to customer, which is when AngelCab loses the control over the product.

4.4.2 Outcomes to create User Value with Service Offerings

In a b2c PSS business model, the lack of feeling ownership has to be compensate in regards of service offerings of the function transportation of a child and what that means to the one using the stroller, i.e. what services that could ease the users everyday life in direct concerns to the product stroller but also other indirect services. The user most feel a pull-factor in regard to choosing this PSS Model Stroller over another Conventional Stroller.

Services that was brought up in the study was connecting to car commuting, such as car seats provided by child insurance offerings, which can be something to further investigate as a provided service. Commuting in general can belong to transportation of a child which can come with great environmental impact, such as owning a car which might be necessary with parenthood. In the matter of fact, owning a car is the second most unsustainable thing a person can do to global warming, where the first one being to have a child, see figure below (Wynes & Nicholas, 2017).
RESULT DISCUSSION – STATUS ANALYSIS

4.4.3 Outcomes to create a Sustainable Stroller with Product Design

The product must stay within the planetary boundaries which might be achieved with a PSS Model Stroller if it is designed in a way that uses modular parts that belongs to the bio-sphere that could be changed for every new user and not affect the ecological sustainability too much. These parts could also be able to adapt some degree of user personalization for strengthen the belonginess of product ownership. The material also needs to be fairly cheap, or at least stay in the same development costs as the AngelCabs strollers, to be able to sustain business.

4.4.4 Outcomes to create a Sustainable Business Model

A research incitement for stroller leasing was to take control over the second-hand market, which saturates the prime market. None of the previously leasing stroller studies got commercialized, which means that the system as a whole lacked something. Much of the inspiration could be find within the b2b PSS models combined with an adapted product and service offerings, such as how it should be sold, transported, disturbed. AngelCab has a locally attendance combined with a strong online platform, which could be something to take inspiration from.

Figure 9 shows an infographic of PSS models of the three different approaches from Annaboda, Bugaboo and AngelCab. Annaboda applied a short-term interval cycle with stroller (0-6 months of use) with repairs at the resellers, but with no change of product design, which applies to all of them, that is there major flaw of unsuccess. Bugaboos stroller leasing ended up affecting the environment even more than a linear model, since they took the approach of pleasing the users to the point of changing cosmetic parts within the same use-phase. They also let the third user keep the stroller as a Conventional Stroller, which makes the responsibilities over the material resources unknown. AngelCab might have had the biggest opportunity of success of staying within the planetary boundaries if they adopted a subscription payment model. Now they just stayed sustainable in one use-phase and then went the same path as Bugaboo, into the unknown of provider responsibility. The future challenges of a PSS business model in comparison to a conventional is displayed in figure 10. This highlights the importance of prolong the life cycle with small incitement of refurbishment in-between the use-phases, where the approach of refurbishment should adapt knowledge contribution from circular economy design logic.
Figure 9 shows an infographic over the three leasing approaches from status analyses.

Figure 10 shows a comparison between a Conventional- and PSS Model Stroll business model.
5  Service Design

5.1  Introduction

This chapter will cover the information gathered concerning the user centric values and needs by investigating the conclusions from the previously chapter. The information was gathered by an online survey which results in statistics, then continues with a qualitative study in the form of interviews, which leads to a creation of a user persona. These results are then discussed in chapter 9.

5.2  Customer Survey

Below follows the result from the survey posted on the Facebook group “Barnvagnar!” (Lavfors, et al., 2019), which in Swedish means strollers. The raw data, with its original languish, can be found in appendix 7. The survey was put online for one week and got closed when the reply frequencies slowed down. The structure of the result is first presented in background statistics and then followed by correlating statistics.

5.2.1  Background statistics

*Figure 16-18* below covers some demographical questions of ‘type of living’, ‘size of place – where living’ and ‘family income after tax’; 417 people answered the survey.

![Pie chart showing the distribution of different types of places where people live.](image)

*Figure 11 - What kind of place would you define that you and your family live in?*
Figure 12 - Do you and your family live in one of the following housing types?

Figure 13 - What is your family’s total income after tax?

Figure 19 illustrates what kind of stroller brands the respondents had, which was multi-choice question, where 16% of the respondents had one stroller, 37% had two strollers, 21% had three strollers, 13% had four strollers and 12% had five strollers (see appendix 7 – question group 7). Hence, the over hundred percent reply frequency in figure 19, since the respondent could choose more than one option. The three most popular brands was: Emmaljunga (43%), Bugaboo (31%) and Babyjogger (21%), or Britax and Brio combined (30%), which would place them on a third place, since they have the same owner company, which got divided into Brio and Britax in 2013 (Takanen, 2013).
When asking about how they procured their strollers, the majority (77%) answered that they bought it new, while 43% answered that they bought it second-hand, notice that this was also a multi-option question, since many users has more than one stroller. In some cases, a close relative bought a new stroller (10%) to the user, while it also occurred that a close relative bought a second-hand stroller (4%) as a gift as well – the close relative was often a parent or parent-in-law to the one using the stroller. (Appendix 7 – question group 3).

There was no significant price category that stood out when asking about the price of the stroller, see the table down below. However, one conclusion is that 50% owns cheaper strollers, while 50% owns more expensive strollers, if the line is drawn at 8.000 SEK.

Table 1 present what the respondents answered in regard to what they paid for their strollers.

<table>
<thead>
<tr>
<th>Price Category</th>
<th>0-3.000 SEK</th>
<th>3.000-5.000 SEK</th>
<th>5.000-8.000 SEK</th>
<th>8.000-10.000 SEK</th>
<th>10.000-12.000 SEK</th>
<th>More than 12.000 SEK</th>
<th>Do not want to disclose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11%</td>
<td>19%</td>
<td>19%</td>
<td>18%</td>
<td>15%</td>
<td>17%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Something that was significant, was that the user strongly wanted to see, feel and try the stroller before purchasing it (87%), while some would be confident to buy it online if they knew and trusted the brand. Some responses also indicated on trying out the stroller at a reseller and then order it online to a more affordable price or buy it second-hand. (Appendix 7 – question group 3)

In the survey the respondents got asked to value different kind of characteristics a stroller can have, which is displayed in figure 20 followed by what they answered. ‘Safety’ followed by ‘comfortable for the child’, ‘easy to drive’ and ‘high product quality’ was considered most crucial, which might go hand in hand, while ‘aesthetically appealing’ also scored high. The brand loyalty, however, gave a diverse plot, which indicates that other features are higher valued, and that the customer are willing to choose the brand who is considered most safe – for example. The category ‘environmentally friendly produced’ was not consider as crucial but semi-important or as a bonus by the majority, while 51 people saw it as not important at all. (Appendix 7 – question group 4)
Figure 15 illustrates the plot of ‘how do you value the following characteristics of a stroller?’

The respondents got the option to add a comment with other characteristics that they valued, and these comments where the most common: “the total weight should be low”, “to be able to store/carry other things in the stroller, such as baby utilities or store groceries when shopping”, “be ergonomic for the one who drives the stroller” and “have plenty of add-ons available on the market” (quotes are taken from appendix 7 – section 4, and represents general comments).

According to the survey in a multi-choice question, 92% of 417 respondents stated that they take the car when ‘transporting themselves and the child a longer distance than they are comfortable to walk’, while 39% also uses public transportation and 10% rides the bike when commuting in their everyday life. Out of those respondents, 383 people answered the question ‘if they bought a car due to their child(ren)’, where 12% stated that they did (all data could be found in appendix 7 – section 5).

Here are some quotes from the respondents developing their answer:

“We have family quite far away and we felt that longer bus trips with a small child were not optimal or safe. And that the purchase of food, diapers etc. would be easier with a car.”

“Needed to facilitate the everyday life, to get faster back and forth from work, shopping etc. Was planning on getting a car before but it reached the tipping point when we got a child.”

“Living in a smaller town outside the city. When the third child arrived, it was difficult to get the time to suffice with everything, the buses does not run often and the youngest [child] constantly yells the times I tried to go on the bus, which made me avoid it. At last we got a car.”

“We sold our car when we got children when we lived in the central city. Now we have bought a house and the child is close to two years, we have bought a car again as there is no access to a car pool nearby.”
“When child no. 2 came, everything with packing and logistics [got harder to manage], then we ended with renting and bought a car of our own, plus we moved from the south of Stockholm to a smaller place where a car is necessary, unfortunately.”

All the quotes are found in appendix 7 – section 5, in its original languish (Swedish).

In figure 21 the respondents got asked what they are planning to do with their stroller if they planning to have more children and what they will do when they not planning to have more children (figure 22). In the first chart, the scenario of ‘My family’s children are so close in age, so when one child is finished with the stroller, the other child takes over the use of it’, ‘Store the stroller to the next child’ and ‘Sell it as second-hand’, which represented almost one-third each of the answers. In the second chart, the scenario of ‘Selling it as second-hand’ represented the majority of the answers (84%). (Appendix 7 – question group 7).

Figure 16 - If your family has or is planning on having more children, what do you planning to do with the stroller during the time it is not used?

Figure 17 - After your family’s stroller period is definitely over, what will you do with the stroller(s)?
Out of everyone who answered this survey, 23% was positive to try the function that ‘provided monthly subscription service that included upgrades throughout the child’s growth’, while 38% answered perhaps and 39% was negative to that kind of service (appendix 7 – section 8).

This is some quotes that representing the yes, perhaps, no and what kind of features they would like to be provided in this kind of service:

“A good idea where you always have only what you need. For example, you rent the frame, and then you rent your own carrycot seat / bed. While your baby is growing, you can change his / her carrycot according to age. Various options with extra equipment, such as rain cover etc. Also, possibility of addition with car seat.”

“I would probably do it if it would not cost me more than a new stroller and it would be awesome if it included updating the stroller type, new cushion, service, tires, repair, accessories and it should be easy to get hold of.”

“Sounds interesting. To be able to change after the need; stroller-sulky, duo-stroller with standing board. But I would also like to have the choice of bike cart and jogging stroller.”

“It should be guaranteed allergy-friendly stroller, where you cannot have neither fur animals nor be smokers. I believe that, since it is the most important thing [the child] you have, the service must be “bulletproof”. That there is guaranteed safe strollers, where neither mold, fur animals nor cigarette scent and substances are present.”

“Often unprofitable and adds to consumption, which should be reduced for the environments sake.”

“It is important for us not to feel that it is someone else’s stroller, as we use it for everything. Such as: grocery shopping, walking in the forest etc. The life expectancy of a stroller differs depending on how it is used, so I would not like to rent myself only because I don’t have to think about the next user”

All quotes are found in appendix 7 – section 8, in its original languish (Swedish).

5.2.2 Correlation Statistics

Looking at the different ways of transportation at a longer distance than the user is comfortable to walk. By filtering down the users who lives in a medium-sized city and upwards, due to the assumption of a “better” infrastructure in bigger cities – in regard of accessibility to public transportation, frequency in public transportation and car pools availability. Then, the result shows that 11% of the respondents bought a car in relation to having a child. By narrow it down even further, with the filter of: users living in medium-sized city and upwards, living in an apartment, the result shows that 20% of the respondents bought a car in relation of having a child. Comparing that to the stroller users who lives in smaller places, the result shows that 12% of those people bought a car in relation of having a child.

5.3 Qualitative Interviews with Stroller Users

Four (P1-P4) interviews were conducted to get a user perspective from stroller owners. The questions addressed how their current situation is and what potentially service features they wish for, that could ease their everyday life in regards of transportation of a child. The conversation is based on the interview guide, found in Appendix 2 and 3.
Table 2 shows the respondents from the qualitative interview.

<table>
<thead>
<tr>
<th>User</th>
<th>User type</th>
<th>Number of children</th>
<th>Of whom uses stroller</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Private</td>
<td>3</td>
<td>2</td>
<td>Karlstad</td>
</tr>
<tr>
<td>P2</td>
<td>Private</td>
<td>2</td>
<td>2</td>
<td>Stockholm</td>
</tr>
<tr>
<td>P3</td>
<td>Private</td>
<td>0 (expecting)</td>
<td>0</td>
<td>Stockholm</td>
</tr>
<tr>
<td>P4</td>
<td>Organization</td>
<td>Several children at the daycare center</td>
<td>Several</td>
<td>Karlstad</td>
</tr>
</tbody>
</table>

5.3.1 Results from Interview with User 1

P1 sees the family’s two strollers as a helping tool that they cannot manage without in their everyday lives. The family has one stroller that they can fit two children in, for everyday use, and one stroller with two seats for running and cycling. Since P1 lives in Karlstad, which is a medium sized city, the distances are not that far, which makes them commute by walking or cycling as much as possible. P1 have a car, which is most used when going on longer trips or when doing the weekly grocery shopping.

P1 stresses that parenthood comes with a lot of time-consuming activities in regard of having children, such as washing, shopping, spending time with the kids, where the last mention is the one of importance, which means that a service that could ease that living situation would be something of interest. One good thing that P1 has notice with the color of the stroller’s fabric is that it camouflages the dirt and does not have to be washed very often, as an example of a feature P1 values today. The fabric of the carrycot does however get very sun bleached, which is something that P1 has exchanged because of that.

P1 cares for the environment, for that reason P1 decided to buy the strollers second hand, but bought it from friends and family, due to the benefits of knowing the history of the stroller and knowing that the stroller to be in good condition. The features that P1 values most of the stroller, is that it has many compartments to put things in and that it is possible to position and swap the carrycot.

5.3.2 Results from Interview with User 2

P2 are at the second stroller, since the family had to upgrade to a double carrycot model due to the two children that are close in age. P2 explains that they did not know that much of what features they was supposed to look for when they purchased the first one. That is why P2 really like the current features of the Bugaboo Donkey they now have. Features like placing the carrycot at different height’s and angles, and also the many compartments to put things in, since they live in Stockholm and using it for everything, like a vehicle. When P2 bought the stroller, P2 first went to a physical reseller to get a sense of feel of the stroller and then went online and order it for a cheaper price.

This family does not have a car and are often commuting with public transportation, such as bus and metro. The metro is fine, because Stockholm’s subway system with elevators are well developed and there is often space to store the stroller when riding the metro. The bus, however, could be very crowded and if there is another stroller on the bus, it could cause delays because of that, which disrupt the situation and makes it hard to plan and causes anxiety. When P2 is going for more demanding trips, such as monthly based grocery shopping or IKEA, the family often rent a car to save some hassle and time.

P2 is planning to sell the stroller on Blocket when the family no longer needs it, P2 stresses that there is a good second hand value on Bugaboo strollers, the only thing that worries P2 is that the stroller gets exposed to a lot of damage, since the chassis is being treated as a fender in the everyday situation of being out and about.
P2 would wish for a service that provided expertise guidance of how the stroller works and what preference to think of, such as mediating that knowledge the P2 has now after two children, but in the first place. The service of an updated plan according to the child’s growth would also be a feature that will suit an urban family with not that much space.

5.3.3 Results from Interview with User 3

Style might overcome function in P3’s case, overall features that transports the child from A to B in a safe way, with the addition of being able to store some stuff in the stroller compartment. P3 and P3’s partner has not done so much research, but the Bugaboo Fox seemed popular and quite good looking, which made them buy that one. They bought the stroller new since P3 really want a new stroller, where no other children have been and made it messy. After they are done using the stroller P3 hopes that the stroller is going to be in good conditions, so someone will buy it, which seems like the easiest way of getting rid of it. But P3 is a bit concerned about that, since both P3 and P3’s partner is not that careful and money is really not that big of an issue, the concern lays in keeping it in good condition so that someone will buy it, for P3 to get rid of it, rather than getting some value back.

One big obstacle that comes with the stroller is that it does not fit in the elevator to P3’s home without taking it apart, other concerns is that in the winter, the wheels will get wet which might ruin the floor in the apartment.

About commuting, P3 think that walking and taking busses will be most common and sometimes renting a car and take taxi when going for a longer distance. P3 believes that a city as Stockholm already has great range of commuting alternatives and do not believe in an additional service connected to the stroller would ease their life.

5.3.4 Results from Interview with User 4

There are strollers that are adopted for an organization use, such as daycare centers. These strollers are more robust and does not come with any appealing cosmetic and fashion trends, rather cheap synthetic material that is easy to clean and wipe off the dirt from. The strollers are also simple constructed and look the same year after years, which means that the parts easily can be replaced when being broken, provided by the stroller provider. P4 has nothing to complain about of having this kind of strollers in an organization, since the strollers are lower in price compared to strollers aimed for the private market. Since the stroller’s design stays the same, the stroller provider is very knowing about their product and can therefor consult with good customer support. Regarding added service features, P4 expresses that regular maintenance on a yearly basis would be appreciated, since it is better to acknowledge damage before it brakes due to risks of accidences that can happen if it gets broken when in use.

The need of strollers on a daycare center is because the parents drops off the children without their own strollers, since they often arrive in car or by bicycle. The daycare strollers are mainly used for the younger children, to sleep in and does not get moved as much, only when daytrips occur. This, in combination with the simple design and the ability to easily change parts, makes these strollers very durable, which makes them last up to 15 years, according to P4.

5.4 User Personas

Below follows a description of a stroller users who represent a user type that can be suitable for this kind of stroller service. This user will later be placed in in a Customer Journey Map in chapter 8, as a tangible recourse when validating the stroller system concept.
Name: Jane
Age: 28
Living Situation: A three-room apartment in central Stockholm.
Occupation: Doing a PhD in Post Humanism and Robotic Sciences at KTH, which is occasionally very stressful and makes her go to conferences around the world.
Family: Jane and her wife Frida live together with their newborn son Roger in their apartment. They often spend weekends at Frida’s parents, just outside Stockholm. Frida’s parents have a small eco-farm and Roger always smiles when he stares at the cows, which Jane and Frida appreciate to have a son that seems to like animals.
Technical Ability: Since Jane are working with both technical and human sciences, she often interacts and developing advanced technology, that is why she wants that regular everyday technology ‘to just work’ and be a helping tool.
Motivation: Both Jane and Frida are very concerned about the ongoing climate change. Since Jane are doing research about post humanism, she is very aware about the human impact on the climate and therefore decided to become vegan, which is a hot topic in the family, since Frida is a farmer’s girl and loves her meat. Frida does give Jane a hard time about her many flights in her work and argues that it is worse than her eating habits. But overall, they try to live as sustainable as possible.
Goal: Jane want to root a sustainable lifestyle from the start for Roger’s childhood and always try to find the right balance between the price, if it is eco-friendly and if it is good working conditions for the onest who provide the product or service. Now the goal is to find a suitable stroller that is in line with her values.

5.5 Key Outcomes from a User Perspective

The most essential feature of a stroller is that it should be safe, easy to drive and take with you and be aesthetical appealing according to the stroller users. But when scratching the surface of what they really use the stroller for, it ends up being much more. It is a tool in their everyday life that helps them with obvious tasks such as transporting the child, but the stroller also limits the everyday life, in ways when commuting longer distance than the user is comfortable to walk. Public transportation can be a hassle which sometimes ends up with a buying of a car to do grocery shopping and visit friends and family. A way to address this and design out the need of owning a car could be to offer a car pool service for the occasions such as visiting friends and family. The stroller system could also connect to a grocery and child items (such as diapers) delivery to the users’ home, since that is a regular commute concerning parenthood and would ease the everyday life.

The user concerns’ about a not new stroller’s quality which was first raised in the literature study which also got confirmed in this survey, which strengthens the argument of providing a stroller that should be modular and the modular parts should have low environmental impact to fulfill RQ1 to provide a stroller that has a 70-95% to lower CO₂e footprint than a Conventional Stroller. The reason behind
that concern is that the stroller gets wearied out and then the user can buy a second-hand stroller instead.

It seems to be a usual scenario when the users buy the strollers, that they prefer to see and feel it in reality and then buys it cheaper online or second-hand. A way to solve that issue from a company standpoint is to offer that service of knowledge about the stroller that especially first-time buyers wants, in similarities what AngelCab does with their concept stores.

The infographic below negotiates the essential outcome from the survey and interviews combined in one figure. The interview with the daycare organization is taken out of consideration, since that business model did not seem to have that large environmental impact and the service provided from this kind of stroller provider also seems to work good enough. The largest degree of impacting a more sustainable business model will therefore be applied to transform the b2c market.

From left to right in figure 18: illustrates the amount of stroller users who are asked in survey and interview combined, schematics of geographic living, how the stroller user commute (multi-choice question), a usual way of purchasing a stroller, how they values different features and their view of a stroller as a service. The figure is just a schematic illustration, for full understanding – read back of this chapter.

“20% bought a car in relation to having a child”

“35% 45% 20% 39% 10% 92%”

“We have family quite far away and we felt that longer bus trips with a small child were not optimal or safe. And that the purchase of food, diapers etc. would be easier with a car.”

“It is important for us not to feel that it is someone else’s stroller, as we use it for everything. Such as: grocery shopping, walking in the forest etc. The life expectancy of a stroller differs depending on how it is used, so I would not like to rent myself only because I don’t have to think about the next user”

“Stroller as a service?”

“High product quality
Low environmentally impact
Easy to drive
Comfortable for the child
Be safe
Aesthetically appealing
Not at all important
Somewhat important
Written important
Very important”

“... would probably do it if it would not cost me more than a new stroller and it would be awesome if it included updating the stroller type, new cushion, service, tires, repair, accessories and it should be easy to get hold of.”

Figure 18 shows the most essential outcomes from the survey and interviews in a schematic image.
6 Product Design

6.1 Introduction

This chapter will cover the ‘P’ in the PSS, which stands for product and contains how it is designed, what material that is used, why it is suitable for repairs and refurbishment, its environmental footprint, and how it could be produced by reflecting over the prototype that is created. The design of the product is based on the outcomes from chapter 5 and the key outcomes from the previously chapter.

The figure below is the supposed PSS Model Stroller that is made in CAD. From here and on, the stroller gets its product name: Ease Stroller, due to it is created to ease the user’s everyday life, which will be explained throughout this chapter and the following chapters.

![Figure 19 shows the CAD model of the supposed PSS Model Stroller, which has got its product name: Ease Stroller.](image)

6.2 Design

The design is based on a four-layer modular design, where planned obsolescence is applied on one layer, which is not a term that is usually associated with sustainability. The form factor silhouette at first sight could be perceived for a Conventional Stroller, which is true, it is inspired by the strollers incorporated in this project, i.e. AngelCabs Urban stroller and the Brio Smile stroller. But when looking closer, the bio-based material disrupts that feeling of conventional and articulates the purpose of ecological sustainability.

6.2.1 Assemble

As figure 16 illustrates, the modularity of this design plays a major role for it to be able of refurbishment in-between the use-phases. Thus the ‘four-layer’ assemble layout, which purposes differs from each other. Layer one: is the base of the chassis, i.e. the “skeleton frame” made out of durable stainless steel. Layer two: is the parts with planned obsolescence and consists of the fiber-based carrycot and the outer solid wood chassis frame. The choice of bio-based material is due to the low environmental impact, in the matter of fact, bio-based material binds CO₂ during its growth-phase (see table 3) due to photosynthesis and capture it in the material, i.e. Carbon Capturing and Storage (CCS). Layer three: defines the ergonomic parts, which is the madras that the child lays on and the bio-based fabric sleeve.
that the child lays in, in the carrycot. **Layer four:** is the “standard” parts, such as wheels, folding mechanism, joints and connections.

The *layer one’s* main function is to keep the overall construction dimensionally stable and prevent material failure and fatigue, which the solid wood cannot guarantee. The skeleton frame serves the function of being a rig for the assembler staff when assembling in-between the use-phases and the steel pipe also houses all of the mechanics for the folding mechanism (see *figure* below), which prevents the assembler staff from touching that and reduces the risks of assembling failure.

The figure below shows a cutout split section over the folding mechanism and the two rods that are joint in the folding mechanism in the center of the stroller. Where \( F_1 \) is the force in the wire that occurs when pulling the activator – close to the handlebar, \( F_s \) is the spring force and \( M \) is the moment force that enables when: \( F_1 > F_s \), \( L_1 = 0 \) and \( L_2 = 0 \).

**Figure 20** shows a cutout split section over the folding mechanism.

### 6.2.2 Refurbishment

From the conclusions in *chapter 4*, which also gets substantiated in *chapter 5*, in the *Customer Survey* and *Qualitative Interview* section, about the importance of a fresh, “as new” standard product, if the customer is willing to subscribe to a stroller service. This could be achieved with the choice of bio-based material that is produced locally, which works as a CCS and are therefore beneficial for the environment. This is why planned obsolescence in this case are ecological sustainable and fulfils the users requested standard. This raises a need of someone who can assemble these new parts and control, clean or repair the other *layers* of the design. It could adopt an IKEA style approach where the users assembles the product themselves, have dedicated Ease Stroller’s stores with refurbish workshops, send it by transport to an Ease Stroller factory, or use contract workers who can pop up like a ‘Ease Service Hub’ wherever the users are located. By using the concept of a Service Hub with work performed on contract would lower the overall costs and simultaneously control the provider responsibility.

### 6.3 Material

This section will provide the evidence of the environmental impact result that is measurable to predict in this concept stage, by performing an LCA of the material of the Ease Stroller. To compare the result, a second-hand stroller was bought as a reference for the 70-95% of GHG reduction that is necessary.
6.3.1 Material Properties

A physical product consists of materials, hence the importance of selecting the right material for right purposes in regards of manufacturing, strength characteristics, durability, environmental impact, intent use, costs, etc. A Conventional Stroller of today, mainly consists of aluminum, synthetic fabric, cotton, plastic and rubber. The consistent material trend throughout the Conventional Stroller line have to do with the relative low weight in combination with a relatively good strength, of the use of aluminum in comparison to steel for example, which is three times heavier (see table below). In regards of manufacturing from cradle-to-gate by comparing the two materials (i.e. aluminum and steel), steel has a quite significant lower environmental impact in regards of GHG emissions than aluminum, where also the raw material of making steel has a lot of virgin resources in Sweden, which not is the case with aluminum (Eco Invent, 2019). However, taking the holistic view of cradle-to-grave and assuming 100% recycling, then aluminum uses less energy than steel and are in that case more beneficial (Eco Invent, 2019). Thus, steel in a long-term use be more beneficial over aluminum. All these material mention, are based on long stored fossil resources, which is why bio-based material can contribute to a better environment. Untreated solid wood is better than all other mention material when looking at cradle-to-gate, which also capture the CO₂ in the material and contributes to a better environment (Petersen & Solberg, 2003 ; Erlandsson, et al., 2018).

The carrycot is where the soft materials are (i.e. synthetic fabric and cotton in a Conventional Stroller), to keep the child comfortable and protected from weather conditions. Cotton in general, has a quite large environmental impact, both regarding GHG emissions and water use (Eco Invent, 2019). With the use of synthetic fabric there is a risk of micro plastics in water, which is the same case with plastic (Cole, et al., 2011 ; IPCC, 2018), not to mention the distances and sometimes the social sustainability situation for those who works in the factory’s in Asia where most of the fabric and plastic manufacturing takes place (Plastic Everywhere!, 2018). The opportunity to use bio-based material instead could be a way of improving the ecological sustainability actions. Durapulp is a bio-degradable fiber-base material which contains 70% pulp fiber and 30% polylactic acid, developed by Södra, which scope is to take market from plastic use (Hermansson, et al., 2016 ; Södra, 2019). The Durapulp material comes on a roll, which could be cut into wished dimension, placed in three-dimensional form then add pressure and heat to lock it in wished 3D-shape (Södra, 2019). The material mentioned above are compared to each other (by 1 kg input material) in terms of: density, strength and CO₂e, displayed in table 1, where Eco Invent (2019) is the reference to the material except the ones that are market with other references.

Table 3 shows the material property: density, and the GWP impact for 1 kg virgin material.

<table>
<thead>
<tr>
<th>Virgin Material (1 kg)</th>
<th>Density (kg/m³)</th>
<th>GWP (kgCO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>2700</td>
<td>10,2</td>
</tr>
<tr>
<td>Steel</td>
<td>7900</td>
<td>1,6</td>
</tr>
<tr>
<td>Pine</td>
<td>480</td>
<td>0,3</td>
</tr>
<tr>
<td>Durapulp**</td>
<td>755</td>
<td>&gt;1</td>
</tr>
<tr>
<td>Rubber</td>
<td>940</td>
<td>2,6</td>
</tr>
<tr>
<td>Plastic</td>
<td>946</td>
<td>2</td>
</tr>
<tr>
<td>Cotton</td>
<td>-</td>
<td>20,2</td>
</tr>
<tr>
<td>Fiber-based fabric</td>
<td>-</td>
<td>3,3</td>
</tr>
<tr>
<td>Synthetic</td>
<td>-</td>
<td>2,7</td>
</tr>
</tbody>
</table>

§ (Dahlgren, et al., 2013)
** (Hermansson, et al., 2016)
6.3.2 Conventional Stroller Teardown

The second-hand Conventional Stroller got teardown because of the need of measure the weight, as input data for the LCA. *Figure 18* shows the BRIO Smile when it is disassembled, but it was necessary to separate the parts into its own specific material, to be able to determine the correct weight. That hassle was also done to be able to take some of the BRIO parts to implement it in the Physical Prototype. The story that Karger (2019) told about monolithic cast plastic and synthetic material in mass produced strollers come to be proven in the teardown, which also reviled the design to almost be impossible to repair due to glued and riveted joints.

![Figure 18 shows the BRIO Smile when it is disassembled.](image)

*Figure 21 shows the second-hand Conventional Stroller: BRIO Smile.*

6.3.3 Result from the Life Cycle Assessment

The following tables below (Table 4-6) presents the result from the LCA made on the second-hand Conventional Stroller BRIO Smile and the supposed PSS Model Stroller made in CAD, which represent a fully development of a product: Ease Stroller. The result from them are then compared to each other, in regards of GHG emissions. The LCA tool and data source is the same in both models, which makes them fully comparable. Ang & Yifan (2012) LCA report is also discussed further down in this chapter as a comparing index. The original input data and result from the LCA Excel templet are included in appendix 4 and 5.

*Table 4* is the result of the LCA made on the Conventional Stroller. The metal components were most found in the chassis (frame), textiles in the carrycot, the plastic in joints and connections, and the rubber in the wheels. The LCA includes cradle-to-gate, with raw material from Asia, production in Europe and ship transportation, use-phase and EoL. The use phase, however, is set at zero in the scope of the LCA, since a stroller is a passive product, but will eventually be discussed in the two next chapters *Service Design* and *System Design*. As *table 2* shows, the GHG emissions over the life cycle (cradle-to-grave) for the Conventional Stroller is 108 kgCO$_2$e.
Table 4 shows the result of the LCA for the BRIO Smile.

<table>
<thead>
<tr>
<th>Input Material</th>
<th>Mass (kg)</th>
<th>Inventory Result CO2 (kg)</th>
<th>kgCO2e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>6,6</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>1</td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td>1,9</td>
<td>4,6</td>
<td></td>
</tr>
<tr>
<td>Polyester (PET)</td>
<td>2</td>
<td>5,4</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>1</td>
<td>19,3</td>
<td></td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>1</td>
<td>2,5</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>12,5</strong></td>
<td><strong>93,8</strong></td>
<td><strong>108,4</strong></td>
</tr>
</tbody>
</table>

Table 5 shows the result from the supposed PSS Model Stroller, where the material such as pinewood and steel (stainless steel) are locally attended in Sweden to value the Swedish resources, quality and environmental impact. Since the PSS Model Stroller are designed to last longer than a Conventional Stroller, the life cycle is split into three sections: ‘full’ which is the full life cycle from cradle-to-grave, ‘one’ which swaps out those components after one use phase, i.e. changes in-between every user, and ‘three’ which swaps out those components after every third use phase. The GHG emissions over the life cycle (cradle-to-grave) for the PSS Model Stroller is 27 kgCO2e, which already in the product design is lower than the Conventional Stroller.

By only looking at the product design out of one use-phase in a life cycle, the PSS Model Stroller is 66% better in terms of GHG emissions. The table below also has some highlighted cells in yellow in three places, which indicates the necessary GHG emissions reduction of 70-95% recommendations from IPCC, in this century.
Table 6 shows the mass (M) comparison of GHG emissions between the PSS Model Stroller and the Conventional Stroller.

<table>
<thead>
<tr>
<th>n</th>
<th>M(PSS) [kgCO2e]</th>
<th>M(CS) [kgCO2e]</th>
<th>M(PSS) GHG Reduction from M(CS) n=1</th>
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6.4 Physical Prototype

The Physical Prototype of the Ease Stroller provides knowledge contribution of what steps that has to be done and how long time it will take when producing the product. A prototype is a simplification of the reality but gives tactile feedback that helps when developing a new product, even though this prototype is not a direct translation of the CAD-model of the Ease Stroller. The prototype also worked as a probe or artefact for the validation process, which is further described in Service Prototype in the next chapter.

Due to time limitations the chassis were the only component that was prototyped, which most reflects the look of it, that will say, the mechanics to fold it was not developed since the skeleton frame do not exist. The wooden frame for the prototype was sawn from a log of pinewood to be able to pick nice pieces from the log and make it into smaller pieces, close to the final dimension. Then the wood pieces got planed to its final box-dimensions as a preparation for the CNC-machine to make the final profile (see some process pictures in appendix 6). This process is quite slow for a manufacturing scenario and according to Larsson and Matsson (2019) a real production would demand a “specific” machine that will do the process in one step from the box-dimensions, i.e. an assemble of tools of (see figure 22)

Figure 22 describes how a real production scenario the wooden parts could look like, with an assemble of tools that creates a machine that does the socket for the skeleton frame, planer the bottom surface and milling the profile surface.
The final result of the prototype is seen in *figure 23*, with wooden chassis. The carrycot, wheels and handlebar are taken from the BRIO stroller, and a front wheel housing was made at the Linköping University Campus workshop facility.

*Figure 23 shows the final result of the PSS Model Stroller prototype, i.e. the “Ease Stroller”.*

### 6.5 Key Outcomes from a Provider Perspective

The product design takes its aesthetics inspiration from the Conventional Strollers covered in this thesis combined with the degree of refurbishment aspects that a PSS model design needs to be able to run through several use-phases, designed from a circular economy perspective (Bakker, et al., 2014). The amount of number (n) of use-phases it has to run to fulfil IPCC and this projects goal (RQ1) is four to six use-phases (see table above), which represents about 15-20 years for layer one.

The material choice comes down to what is necessary to use in terms of bio-based material (inspired by figure 4), the pinewood seems to be a good option since it is a fairly cheap material that Sweden has a lot of, and the product manufacturing is reasonable.

Concerning the carrycot, which was not build as a prototype, makes it harder to estimate. Assuming the use of fiber-based material, such as cardboard or Durapulp (which not is a commercial product) that are considered cheaper material, since the conventional use of that material is aimed for one-time use. That is also its strength, since it is very adaptable and can go the same path as the wood assembly, i.e. market founded work, where the product can be shaped at the Service Hub, using a 3D template, pressure and heat (Södra, 2019). However, the use of the material Durapulp seems to be to-good-to-be-true and it is strange that it is not a commercialized product. This apprehension came to be correct when *Head of Innovation and New Business* at Södra got contacted to validate the use of Durapulp of the carrycot. The scale of the carrycot would be hard to manufacture and the machines that has to be created to do that work would cost millions (SEK), which is not feasible in the set-up of providing every Service Hub with that kind of machine to have knock-down transportation close to the
users (Bengtsson, 2019). Therefor is the choice of the material for the carrycot viscose, which is implemented in the LCA.
7 System Design

7.1 Introduction

This chapter includes the system level i.e. the business model of “Ease Inc.” which is the imaginary name of the Stroller Service System. The chapter begins with co-creation session result about the overall user experience that could be expected with grounding how a circular business model would sustain economic sustainability. It then continues with an LCC reasoning about the feasibility of the system. The validation is done by a Service Prototype session based on the Service Blueprint that connects the services, products, users and providers in one visual blueprint.

7.2 Co-creation – User Experience

In this project was the co-creation focused on experts of different topics of interest, which was found inhouse at RISE, with the purpose of gaining insights, explore concepts and specify how the holistic view of ‘transportation of a child’ could go from a stroller, towards a transportation system, with the focus on designing out the need of owning a car. The expert in question was Peter Algurén, former CEO of Sunfleet††. Peter Algurén is now working with Sustainable Businesses at RISE, practicing his experience from Sunfleet and implementing that into other innovative projects that emphasis on circularity (RISE, 2018).

Algurén (2019) explained one implementation that was done during his time as CEO at Sunfleet, to create company symbiosis with other companies, which in this case implicated less use time of their cars, which at first gained resistance within the company but then got proven the opposite when new customers/users increased. The symbiosis was made with the company MatHem‡‡, who delivers groceries to customers doorstep, with the purpose of creating an ecosystem to ease MatHem and Sunfleet userbase, everyday life. The deal was a simple thing of just sharing each other’s service and give a discount if the user used both services. This evolved to other company collaborations as well, for example with Houdini§§, with the same kind of deal.

Therefore, Algurén (2019) suggested to create this kind of company symbiosis service for this projects business model as well, due to the goal of ease the users overall experience. In the scope of transportation, then Sunfleet are a good symbiosis company and they already provide the option of children car seat in some of their cars, which could be enhanced in a combined service. To amplify it even more, other business could join as well, such as NTF or IF, who already provide services for car seats.

The figure below is the result of the discussion about how to this business model would gain profit compared to how a linear business models product lose in value and a PSS product shrinks their loss after every new use-phase. However, the costs in the beginning of a new business can be very large, which is why a second credit company can be good to establish to handle all the peripheral and let

†† Sunfleet is a car-pool service that is active in over 50 places in Sweden and offering several different Volvo car models for different purposes (Sunfleet, 2019), more information about Sunfleet could be found in Status Analysis.
‡‡ MatHem is an online grocery store that creates recipes after the customers preference and generate that into meals, to ease the customers life and lower the food waste. It is a subscription service that delivers the groceries to the customers doorstep, at a time that the customer has defined (MatHem, 2019)
§§ Houdini is a sportswear company and brand, famous for their outdoor garment and their sustainability actions (Houdini, 2019).
each specific part of the company manage what they are aimed to do (Algurén, 2019; Cristensen, 2013).

The figure is also a graphic illustration of the forecasting costs displayed in table 7, further down in this chapter, based on the most likely LCA scenario where the Conventional Stroller is used for three use-phases and the PSS Model Stroller is used for four use-phases.

Figure 24 shows a schematic view of a product in a linear business model compared to a product in PSS business model.

7.2.1 Business Structure

Ease Inc. is the umbrella company of a four-group structure: Ease Stroller, Ease Car Pool, Ease Grocery Delivery and Ease Child Insurance. Ease Inc. focus is to deliver a system design in regard to ‘transportation of a child’ to lower the greenhouse gas emissions, which is illustrated in the figure below followed by a description (Algurén, 2019).

Figure 25 shows the business structure of Ease Inc.

Ease Stroller concerns the Product Service System of the business model, with the product fleet of ‘Strollers’ and the Service Hub. The Ease Stroller is a modular design with four main clusters of parts:

- ‘Chassis skeleton’ is the base of the frame, made out of stainless steel and is kept throughout the whole life cycle.
- ‘Chassis surface’ is a combination of a protection layer to the skeleton and exterior. This part is made out of Swedish pine wood and gets exchanged in between every use-phase.
- ‘Fabric’ is made out of wood fiber and is applied to carrycot, hood and sleeve which is placed in the carrycot for comfort for the child. The fabric gets exchange in the same cycle as the chassis surface.
• ‘Other parts’ such as wheels, joints and connections get maintained in between every use phase, and exchanged when needed.

The Service Hub does not consist of own staff, it consists of contract workers who are where the users are. It could be a Bike Shop or other organizations that are run by the municipality, driven by allowance, for people that have a hard time finding a job. Ease contributes with material and equipment to refurbish the strollers and gives education to the contracted staff, for them to deliver a good customer experience for the stroller users.

**Ease Car Pool** does not have a car fleet themselves but is the link to an already existing car pool. Ease Car Pool is the branch to have industry symbiosis with other car pools to make sure to deliver that service to the user if they are in need of a car at the moment.

**Ease Grocery Delivery** is much like Ease Car Pool regarding the structure of finding symbiosis with other already existing companies. It also exists to ease the everyday life for the user and design out the need of owning an own car.

**Ease Child Insurance** is a credit company to allocate risks from the other parts of the company regarding the material flow legal relationships to other companies, etc. But does also have a child insurance product, that protects Ease Inc. products, the child and includes tangible products such as car seats in the car pool cars.

### 7.3 Life Cycle Costing

The LCC is created to get a sense of the costs for the Ease Stroller Service System. The cost calculations are not a true LCC, since that demands real data. Below follows an argumentation that aims to reflect a rough LCC. By keeping figure 24 in mind, a reasonable customer price for the stroller would be the premium price of Conventional Strollers, such as Emmaljunga, Bugaboo and AngelCab, i.e. around 12,000 SEK divided over one use-phase which is about four years. That would set a customer price of 250 SEK per month.

#### 7.3.1 Direct Costs

From the prototype making, it is reasonable to come in the same price range with the Ease Stroller as the AngelCab stroller manufacturing costs, since the setup of production would be small scale, as with AngelCab. AngelCabs manufacturing costs are about 1/3*** of the reseller price of 12,000 SEK, where they claim that the textiles are the most expensive parts. The price per hour in a medium sized workshop (like the one on Linköping University Campus) is 800 SEK/h, if being commercial (Larsson, 2019). With the assemble of tools as figure 22 illustrates, the estimated time to produce parts for one unit is 30 minutes and the input material will cost 125 SEK (XL Bygg, 2019). The assembly work considering the wood will be done at the Service Hub, which is free due to label market founded work. The wood parts will end up costing 525 SEK excluding transportation for one unit.

The metal work, i.e. the ‘skeleton frame’, direct material cost is 400 SEK (Tibnor, 2019), adding additional mechanic parts, such as folding mechanism, will add additional 400 SEK in material. The metal work and assembly are a bit more demanding, since it includes several steps: water cutting, *** (Karger, 2019) claims (see 3.4.3 Production) that their profit is 1/3 of the reseller price, which probably indicates 1/3 direct costs, 1/3 overhead costs and 1/3 profit.
bending and rolling, CNC, and welding. This might take three hours in total, isolated to one unit, which makes the total cost to add up to 3.200 SEK for the metal work.

Considering the above reasoning and also adding viscose textiles, standard parts as wheels and screws. The total direct costs could be around 6.000 SEK, which is more than AngelCabs production costs and considering more than other mass-produced Conventional Strollers. But since this is a PSS business model aimed to be circular, the income is allocated on several use-phases as figure 24 illustrates, that was co-created with Alguérén (2019). The beneficial lays in that the most expensive parts (skeleton frame) will be used over and over again on a 15 year basis to fulfill the ecological sustainability goals conducted by the LCA and the cheap parts are the ones being interchangeable, which will make a stroller unit pay itself off when stretching it out on several users, just like the CO₂ impact.

7.3.2 Overhead Costs

Since this is a service system it depends on software’s to maintain communication and logistics, which needs to be developed and also have staff working with it. Other costs come with shipping, which should be minimized as much as possible, thus the layer one structure of the product design that consists of a fleet of strollers constantly in-use, which ideally finds another user close by when the first users use-phase is done.

The additional services that was concluded to ease the user’s everyday life, should just be a logistic system to connect and work out deals for the users, for Ease not to be a grocery and car pool business as well. But is important to gather everything under the same system, even though no in- or outcome in terms of money might come from it, as a direct asset.

7.3.3 Ecological Sustainability outcome from LCC

Almost all material of consideration comes from Swedish bio-based resources (pinewood, viscose/lyocell), the steel production is also well established in Sweden and considering products from Sandvik (2019) over SSAB (2019) then the steel comes from recycled resources. The bio-based textiles are often produced in Sweden, but then shipped to Asia for manufacturing products (Bio Innovation, 2019), this is a management decision and could as well be made more locally. If everything is manufactured in Sweden it will use fairly good energy resources, such as renewable energy or nuclear power as input.

The shipping in this system will be fairly little, since eventually a fleet of strollers will be in a user flow and when it goes from different users, only new bio-based material will be shipped to the Service Hub and assembled close to the user.

7.3.4 Forecasting Costs

The forecasting costs in the table below is very preliminary and are probably a bit too high and could be optimize for production, if that was covered in the thesis. The forecast is created to be a reference value to a Conventional Stroller to give an example how a circular business model could be profitable over time. The calculation is based on the LCA outcome of four use-phases, achieving 76% of GHG reduction, if a Conventional Stroller is used three times.

<table>
<thead>
<tr>
<th>Table 7 show the forecasting costs of PSS Model Stroller of four use-phases.</th>
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<tr>
<td>Manufacturing costs</td>
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<td>Refurbishing costs</td>
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<td>Use-phase 4</td>
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7.4 Service Blueprint

The Service Blueprint on the next two pages illustrates the whole Product Service System scenario: with the product (Ease Stroller), online platform (Ease website – which is prototyped see 7.4.1 or app), the physical location where user picks up the stroller (Service Hub), as a physical evidence of the service. The blueprint also mediates what is happening from a user perspective with user actions and what is happening frontstage. The things that happens frontstage connotes with a backstage action which sometimes relays on support process, such as software systems. The blueprint should be read in a horizontal order, where the arrows indicates the direction of interaction.
Figure 26 shows the Service Blueprint of this Product Service System.
7.4.1 Online Platform

The online platform from a user perspective is included the service blueprint as a ‘physical evidence’ and consist of a user website (see figure 27 below) and mobile application. The user website*** is also rapid prototyped in the software Adobe XD, which the participant interacted with in the service prototype session.

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*** Access to the online prototype: https://xd.adobe.com/view/9c6ce6b7-9d82-4f4e-44c4-6aa5974a1d3b-ea5d/
7.4.2 Service Hub

The Ease Service Hub is the result inspired by AngelCabs way of not using retailers, but also a reflection from the survey statistics and interviews, that the potential stroller customers often use the retailers as a place to tryout the strollers and then buys it online anyway. The Service Hub provides the service of setting up the stroller after the users need that the user has defined online. The user then arrives at the service location to get a product walkthrough and information about the services.

Backstage at the Service Hub, the strollers get maintained and refurbished according to the framework of the product design in-between the use-phases. The Ease Inc. company manage all the logistics to the Service Hubs with product parts and assembling tools. The Service Hubs are driven by contract work of people that works for organizations such as municipalities, which they get their salary from, as a step for social sustainability.

7.5 Service Prototype

Validation session with ‘Anna the Stroller Reviewer’, doing a service prototyping session with the service blueprint, stroller prototype and website prototype as foundation, taking place the 7th of May, which is when the image below is taken.

Anna runs the blog Allt Om Barnvagnar (2019), which in English means “Everything about strollers”. On the blog she reviews strollers, where she has managed to review over 200 strollers. This means that she knows her way around strollers and has an influencer role on stroller customers, and stroller companies wants to get a good review from her to gain new customers. What differentiates this review is that Anna is reflection over a concept and prototypes that has the service function transportation of a child, rather than just a product.
The session went through the steps of the service blueprint, which then resulted in a Customer Journey Map (see figure below) of the first section of the service blueprint, applying the service scenario for the created user persona, that Anna and the facilitator filled in and judged.

Figure 29 shows the Customer Journey Map – developed at the service prototype session.

7.5.1 Outcomes

Anna believes that this kind of service system would suit first-time parents most, since people that already have children tend to save their stroller for the next child and perhaps already has moved from a big town where a car is necessary anyway. That was her other critic for the system, she thinks that this service system only would suit people who live in a big town where having a car is hard to facilitate, such as living in an apartment without a parking spot. Anna thinks that the option of the connecting services is good to have optional and it should also provide the service of delivering baby utilities, such as canned baby food and diapers on a monthly basis.
8 Concluding Discussion

8.1 Result Discussion – Product- Service- & System Design

In a world with limited resources – with the behavior of people like we have a world with endless resources, one could draw the conclusion of an unsustainable past, present and perhaps future. Science proves that the planet Earth is on its way or have past the line of inevitable irreversibility to stable conditions, due to the effect of climate change, caused by humans of today with the beginning of pre-industrial eras (IPCC, 2018). Over consumption and product norms of planned obsolescence, contributes to depleting of this planet’s recourses (Earth Overshoot Day, 2019). The figure below shows the worlds carbon dioxide (CO₂) emissions together with the worlds Gross Domestic Product (GDP), showing a clear relationship between them. This tells the story of climate change and the humans’ way of affecting it through a capitalistic structure that builds upon consumption, most affected by rich and high developed countries (Gore, 2015).

![Graph showing relationship between world GDP and CO₂ emissions](image)

Figure 30 illustrates the world Gross Domestic Product (GDP) (blue line) and the world carbon dioxide (CO₂) emission (red line) in relation to each other (The World Bank GDP; The World Bank CO₂ emissions, 2019).

8.1.1 Major aspects that affects the physical design of a PSS Model Stroller

The product design is inspired by the principals that Bakker, et al. (2014) addresses in *Products that Last*. This stroller combines the first layer of a high-quality construction to be a long-lasting product with the essentials of adding low environmental impact “add-ons” which makes this stroller into a hybrid. The design has considered the aspects of being easy to maintain and at the same time being modular for the environmental benefits, but also be able to update the design after trends with a low degree of change, such as changing color or shape of the wood.

By looking at the result from the LCA, it shows that it is possible to achieve product development that fits within the boundaries that IPCC has mapped out of environmental impact. It might however be in
the lower range, since the most usual scenario might be that a Conventional Stroller are being used by three users (i.e. about 12 years) and therefore only fulfilling the 70% GHG reduction improvement. Comparing these projects two LCAs with Ang & Yifan (2012) stroller LCA result of GWP impact of 321 kgCO₂e shows a large improvement for both the Ease Stroller and the BRIO Smile. That raised the concern of an incorrect LCA somewhere. With consultation with the Environmental Engineering Department at Linköping University, they conducted that this project LCA used correct boundaries and data input, while Ang & Yifan (2012) LCA report did not reveal their appendices with their input data which makes it hard to judge.

Since the carrycot is only in its embryo of theory, it is hard to evaluate how good this will work in practice concerning manufacturing. The idea of using Durapulp with similar properties to cardboard did not work out, which was a too disruptive material idea in reality, which ended up with using bio-based fabric instead. The choice to go with viscose rather than polyester, even though polyester has a lower CO₂e impact, it has other flaws that are connecting to micro plastics which a lot of uncertainties is still to discover from the research world.

The physical prototype contributed with knowledge about the material pine wood, regarding look and feel, how to produce it and a sense of durability. All those stated preferences seem to work for this PSS Model Stroller due to the allowed wear and tear of the wood. The wood design could be even more explored as a protection layer. For example, in the CAD-model design, all the wood parts are in the same surface level as the metal components (front wheel house and folding mechanisms), which makes it that all parts get exposed equal for external damage. Due to the creation of the prototype, this insight could be corrected for a real product. By letting the wood adopt a larger dimension over the metal components, makes it able to protect the metal even more for taking on external damage in use. This also provides the opportunities to refurbish the wood in-between the use-phases, rather than dissolve it. Approaches like sanding the wood or coat it with paint, is possible, to extend the life of the wood. This was not investigated in practice, which must be tested to fully conclude that theory.

8.1.2 PSS related services that support the customer and user to take more ecologically-, economically-, and socially sustainable decisions

The outcome from the online survey and more deeper interviews indicates that a stroller is an essential tool in parenthood, though it does disrupt and change their way of living. The survey gave information that it is usual to have several strollers for different purposes and that many bought their stroller new and wanted to sell it second-hand. This could mean that stroller customers both have new strollers, and second-hand for occasions when they do not want to be careful with the stroller. This is also a “luxury” that people that live bigger has the space for. The survey also indicates that many stroller owner have their stroller pending in time for the next child to use it, which is reasonable to spread out the costs on more children, but it is also a way of wasting resources when it is not in use, which the whole purpose with PSS is to design out. By having a subscription-based payment model, this would address that issue of “resting” resources and in the same time give the opportunity for a stroller provider to provide the right accessories when needed.

A big issue concerning “not new” strollers is that the parents seems skeptical in terms of general wear and tear, hygienics and allergies, which is why the importance of a modular design, where connecting surfaces can be changed in-between the different users, which is addressed and described in previously chapter. Since many users seems to care for the aesthetics, some level of customizing the stroller is necessary to make it desirable, which got applied to the low environmental impact interchangeable parts, to be able to fulfil the customer need while keeping CO₂- levels to the lowest possible.
Parenthood seems to have a connection with car ownership, to address that issue, the service of providing a shared car pool usage was created to design out that desire. As Anna concluded, this would probably only attract people that do not have the possibility to own a car in the first place. The risk with that, is if that service becomes too “good” in terms of user experience, perhaps the service will create a situation for the users, overusing that service, instead of commuting with public transportation and so on. Similar situation has occurred with Uber taking customers from taxi and public transportation sector, which has led to larger environmental impact than before, due to a good and convenient user experience (Bliss, 2018). A way of making that not happen, is to establish a collaboration with the public transportation sector, much like Stockholm Public Transportation already does with their buses (SL, 2019), where they let parents with a stroller ride the busses for free, note that this is only busses and it should be good to extend that to other public transportation systems as well.

8.1.3 How a PSS model stroller can be realized to be more ecological-, economical- and social sustainable than Conventional Strollers

The way of changing consumption patterns is to design something that is better, more affordable and more intuitive than its predecessors, for the market to adapt it. By creating value in every step through services, convenience, durability, features and aesthetics, to mention a few. To lower the environmental impact in-line with the necessary goals of RCP2.6 scenario, with a passive product, the greatest effect is to stretch and stimulate the use-phase of how many cycles it could run before it hits the grave, which figure 31 illustrates by comparing a traditional business model with a PSS business model. The outcome from LCA showed that the most likely scenario to compare was if a Conventional Stroller was used for three use-phases and the PSS Model Stroller was used for four use-phases. Which is not that big of a different, the fact is that the Ease Stroller was 66% more ecological sustainable (in terms of CO₂) from cradle-to-gate which is close to the lower IPCC recommendations already. However, debating more than numbers can tell, a PSS business model do guarantee the provider responsibility, which a linear model does not do and that motivates for a more sustainable product.
The system is conducted around the stroller, by look at how the user interacts with other things in their everyday life in the scope of transportation, which gave the opportunity for a service system to lower the overall environmental impact that a child and a stroller might cause. In terms of the product in the LCA system boundaries, the use-phase it set to zero impact. It is arguable since many users seem to buy a car in relation to having a child, it also arguable to what extent a car pool- and grocery delivery system would have caused in environmental impact. In some cases, it might lower one person’s carbon footprint, but it is also a risk that it could increase a person’s carbon footprint if overusing these services and if it opens up a new kind of usage behavior that would not have appeared with a Conventional Stroller. To conclude the environmental impact of the use-phase, regarding the system as whole, further research has to be done.

8.1.4 Stroller as a Case Study for B2C circular PSS within planetary boundaries

I would say that the stroller is a quite suitable case product for a PSS business model, that can achieve the sustainability goals to stay within the planetary boundaries. The previously studies of PSS strollers are an evidence that the potential for a more circular approach is applicable to a stroller. They did fail to commercialize it, and this thesis cannot, in this stage of age tell if it would be suitable for the market. But it is not a repetition of the previously studies, rather a mapping of the complexity of what was good and bad with the other stroller studies combined with this project’s environmental mapping, human- and user centered design approach.

A B2c PSS stroller has the potential of being a win-win situation for both the stroller provider and the stroller customer/user. Since the economical forecast calculations shows that in a long-term horizon, a circular business model could be more beneficial over a linear (see figure 24 and table 7) and also design out the saturation of second-hand strollers on the market. The customer wins are that a monthly subscription payment can be attractive, but mostly the ability to get access to a high quality product that updates during the use-phase, the additional services gather in the same system and not have to worry over the concerns of getting rid of the product after the use-phase ends.

The stroller gave the knowledge contribution that differential of the environmental impact has to be quite large to make sense of creating a PSS business model, where the stroller is on the line of being suitable or not. There are still uncertainties of how many use-phases a Conventional Stroller gets used and how they end-up being disposed, which is beneficial for a PSS Model Stroller – where this can be controlled. The stroller as a product is also suitable since the general product design has stayed similar throughout many years, which is something that should be of consideration when trying to apply this theory of knowledge to other product. That will say: the silhouette/profile of the product should have a long-term design standard and also have a modular layer where the degree of freedom of design could adopt to trends, but also as this PSS Model Stroller’s design shows, a low environmental impact protection layer is of importance.

8.2 Conclusions

Concluding RQ1 origins back to the material choice, the stroller is a product that gets exposed to a lot of damage that happens in the everyday life of parenthood. Adding to that, the stroller is concerned as a very emotional product that has a lot of demands assigned to it, almost as a miracle product where it should be: safe, stylish, convenient to knock-down and bring with you, easy to drive, have many compartments, etc. Several companies have failed with creating a PSS business model around the stroller, much because of not adopting the product design to the just stated demands from the users and perhaps the timing was not right. A modular design can provide the standard ‘as new’ for every new user. This study cannot yet conclude if this Stroller Service System would have become a success story or not, since it is only a pre-study that maps the potential of success. But the conclusion are that the stroller has to be used and refurbished over and over, aging for 20 years to be able to lower the
CO₂-emissions by 95% and 15 years for the 70%, by using a high quality base with a bio-based shell that can be disposed without affecting the global warming too much.

Concluding RQ2 relies on providing a user-centered service experience around the users need regarding the stroller as a product, which needs to be accessible through modern media of online platforms and tangible places for access the stroller, which is reached through a Service Hub, that contains the eco-values from RQ1. The user-centered values lay in access service solutions that will ease the user’s everyday life, where services such as groceries and items deliveries, embedded child insurance, and the accessibility to use a car when needed, to visit friends and family, was conducted by a user-centered approach. That also has a human-centered sustainability solution, which might design out the need of owning a car, which is positive on all sustainable levels from a society level, which probably would be most realistic in larger cities.

Concluding the packaging of it all, i.e. RQ3 which is addressed at the business model. By creating a business structure with several levels, which enables a whole system to cover all the needs that would ease parenthood. This demands to solve RQ1 and RQ2, while having the long-term circular business agenda of the whole ecosystem. The cons of establish a PSS business model is that it will take some time before earning money compared to a linear business model, where the revenues happen when the product is sold. The pros however, is that after a while the revenues will be spread out in a continual pattern, due to monthly subscription payment. For an established stroller provider this could be realized with a subsidiary, where money can be allocated for that specific business and in the same time not harm the main company’s brand. For a new stroller provider, a PSS business model could be realized with the same structure but where the money comes from interest of potential, which a credit company can provide.

Overall, this kind of PSS b2c model might suit first-time parents most, who lives in larger cities in apartments, which in Sweden’s case would be cites like Stockholm, Gothenburg and Malmö. To be able to maintain a sustaining business with measurable user patterns to be able to provide a realistic amount of stroller fleet and be able to calculate the demands of refurbishment.

### 8.3 Future Research

This study is a first stage of a holistic mapping over a PSS business model, including product-, service- and system design. That makes it not very detailed, therefore I suggest that futures research should be made on all design levels separately, still as a pre-study, to conduct the detailed needs and opportunities. For example, in the product design, the carrycot needs to be prototyped, which this project did not manage to fit within the timeframe. All of these low-fidelity prototypes should be enhanced to high-fidelity prototypes and be piloted in real case scenarios to see true and realistic feedback and money flows.

From this project’s knowledge contributions, there is potential to develop other studies of suitable b2c case products adopted to a PSS business model, similar to this study. But also try to define different methods to use as tool to discover other products potential of adopting a PSS business model.
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Appendices

Appendix 1 – Case Study Structure

Case Study Structure – AngelCab, Berlin – 2019-02-22. Audio recorded with relevant implemented result in chapter 5.

- Project introduction to AngelCab
- Discuss AngelCabs sustainability actions and goals

Can you explain how you are trying to communicate your sustainability actions to your customers?

How is your responsibility over your products after it leaves the store?

Can you describe your production process and responsibility?

What kind of material do you use in your products and is there a reason why you use that kind of material from a sustainable perspective?

Do you measure your environmental impact in any way? If yes, can you explain how? If no, can you describe why? [LCA]

What are your thoughts about climate change and the role of consumer products in that context?

Do you have any thoughts of how to sustain a feasible business model where companies, such as AngelCab, can continue to make revenue and still be environmentally sustainable – in line with global environmental goals?

- Business model

How would you describe your typical consumer?

Have you done any study of who are your typical consumer?

Are you aware of any organization that provides the service ‘transport of children’?

- AngelCabs leasing study

Can you tell me about AngelCabs leasing study, a) why did you do it, b) how did you do it, c) what was the difficulties and d) what was the result and the conclusions after the study was done?

- AngelCabs product portfolio

Would you like to show me AngelCabs products and motivate their purpose?

Do you have any possibilities to sponsor or lend me a stroller or parts of a stroller, for me to modify in a prototype in line with my project goals? (Practicalities)

Appendix 2 – Interview Guide: Organization

Qualitative Interview Questions – Daycare Center for children up to six years of age, Karlstad – 2019-03-13. Audio recorded with relevant implemented result in chapter 9.
1. Do the daycare center have and own strollers, in that case, how did you obtain them?
2. Can you describe what features that are of importance of the strollers?
3. Do you experience larger wear and tear of the stroller in a daycare center if you compare it to a private owned stroller?
4. How do you experience fashion and trend features in regard to the strollers that are used at the daycare center?
5. What are your thoughts about using the stroller as a subscription service, with included updates, maintenance, etc. is included in the service?
6. What would you which for in such a service?

Appendix 3: Interview Guide: Stroller Users


1. Can you explain how your stroller helps you in your everyday situation?
2. Can you explain how your stroller limits you in your everyday situation?
3. What do you think is the most important feature of your stroller?
4. How did you buy your stroller and how was that experience?
5. Can you explain what aspects you consider when choosing stroller and was it some aspect that acted as a tipping point when choosing?
6. What are you going to do with your stroller when you no longer have use for it?
7. If you think about your stroller, can you describe if it has been damaged or wearied out in a particular way, that you did not expect?
8. How regular do you maintain or wash your stroller?
9. Can you explain how you and your child(ren) transporting yourself a distance longer than you are comfortable to walk?
10. What are your thoughts about a subscription service with the function “transportation of a child” and what should such a service include?
Appendix 4 – LCA Data Conventional Stroller

Life Cycle Inventory Data for the Product

Example of how to put in your product data and assumptions

Check under "Unit Processes" to see which processes that are available to you. Make the best assumption from the list if your specific materials are not listed.

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount per FU</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>6.6</td>
<td>kg</td>
</tr>
<tr>
<td>Steel</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Rubber</td>
<td>1.9</td>
<td>kg</td>
</tr>
<tr>
<td>Woven cotton</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Polyester (PET)</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>1.5</td>
<td>kg</td>
</tr>
</tbody>
</table>

Energy during use phase

Electric energy (CENTREL) (MJ)

Transportation

Distance prod. to resale: 15000 km
Weight transported: 13 kg
Ship transport: 195 tonkm

In order to simplify the LCA somewhat we need to make some assumptions regarding end-of-life treatments. We propose (you can test these assumptions) that you use closed-loop recycling with a 50% recycling rate for the metals and 100% incineration for the plastics and packaging waste. When you calculate the end-of-life treatments you can use the following values for electricity use in the recycling and generated energy from incineration.

<table>
<thead>
<tr>
<th>Material</th>
<th>Electricity used in recycling (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling, Steel</td>
<td>1,512</td>
</tr>
<tr>
<td>Recycling, Aluminium</td>
<td>0,6264</td>
</tr>
<tr>
<td>Recycling Copper</td>
<td>0,064652</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generated electricity (MJ/kg)</th>
<th>Generated Heat (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incinerated waste</td>
<td>1,326</td>
</tr>
<tr>
<td></td>
<td>11,934</td>
</tr>
</tbody>
</table>

Example end-of-life treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Treatment rate</th>
<th>Amount (kg)</th>
<th>Used electricity (MJ)</th>
<th>Generated elec. (MJ)</th>
<th>Generated heat (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled aluminium</td>
<td>100%</td>
<td>6,598033327</td>
<td>4,1330088808</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Incineration</td>
<td>100%</td>
<td>4,4</td>
<td>5,8344</td>
<td>5,8344</td>
<td>52,5096</td>
</tr>
<tr>
<td>Recycled steel</td>
<td>100%</td>
<td>1</td>
<td>1,512</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Proceed to "Inventory results" to see an example on how these can be calculated.

Since we assume closed loop recycling this amount affects the amount which should be
## Life Cycle Inventory Data for Unit Processes

These are simplified aggregated data for emissions from cradle-to-gate processes. The emissions presented below are just a selection of the emissions in the full version.

### Metals

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Steel</th>
<th>Aluminium</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (in air)</td>
<td>kg</td>
<td>9.545E-05</td>
<td>2.755E-04</td>
<td>3.053E-03</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.487E+00</td>
<td>5.346E-01</td>
<td>1.780E-01</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>1.372E-02</td>
<td>9.744E-02</td>
<td>7.684E-03</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>kg</td>
<td>1.223E+05</td>
<td>2.683E+04</td>
<td>2.380E+04</td>
</tr>
<tr>
<td>Ethane (HC2:15)</td>
<td>kg</td>
<td>4.271E-13</td>
<td>1.111E-12</td>
<td>1.710E-12</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>5.304E-03</td>
<td>1.642E-02</td>
<td>3.062E-03</td>
</tr>
<tr>
<td>Methane (C2:13)</td>
<td>kg</td>
<td>1.848E-09</td>
<td>4.925E-08</td>
<td>6.412E-09</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
<td>3.729E-03</td>
<td>1.085E-02</td>
<td>1.950E-02</td>
</tr>
<tr>
<td>Phosphorus (in air)</td>
<td>kg</td>
<td>7.476E-08</td>
<td>1.074E-07</td>
<td>1.178E-07</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>3.826E-03</td>
<td>3.582E-02</td>
<td>4.102E-03</td>
</tr>
</tbody>
</table>

### Plastics

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>ABS (Acrylonitrile Butadiene Styrene)</th>
<th>High definition Polyethylene (HDPE)</th>
<th>Low definition Polyethylene (LDPE)</th>
<th>Polypropylene (PP)</th>
<th>Polycarbonate (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (in air)</td>
<td>kg</td>
<td>9.545E-05</td>
<td>2.755E-04</td>
<td>3.053E-03</td>
<td>1.938E-07</td>
<td>2.136E-07</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.487E+00</td>
<td>5.346E-01</td>
<td>1.780E-01</td>
<td>1.563E-00</td>
<td>1.680E-00</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>1.372E-02</td>
<td>9.744E-02</td>
<td>7.684E-03</td>
<td>8.600E-04</td>
<td>1.788E-02</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>kg</td>
<td>1.223E+05</td>
<td>2.683E+04</td>
<td>2.380E+04</td>
<td>8.600E-04</td>
<td>7.798E-08</td>
</tr>
<tr>
<td>Ethane (HC2:15)</td>
<td>kg</td>
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<td>1.111E-12</td>
<td>1.710E-12</td>
<td>8.600E-04</td>
<td>7.798E-08</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
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<tr>
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<tr>
<td>Nitrogen oxides</td>
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<tr>
<td>Phosphorus (in air)</td>
<td>kg</td>
<td>7.476E-08</td>
<td>1.074E-07</td>
<td>1.178E-07</td>
<td>8.600E-04</td>
<td>7.798E-08</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>3.826E-03</td>
<td>3.582E-02</td>
<td>4.102E-03</td>
<td>8.600E-04</td>
<td>7.798E-08</td>
</tr>
</tbody>
</table>

### Energy and heat

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Electricity (CENTRAL)</th>
<th>Electric energy (Chinese electricity mix)</th>
<th>Electric energy (HOKRID)</th>
<th>Heat production from biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (in air)</td>
<td>kg</td>
<td>8.676E-07</td>
<td>1.322E-06</td>
<td>1.095E-06</td>
<td>2.126E-06</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>2.428E-01</td>
<td>2.724E-01</td>
<td>4.574E-02</td>
<td>2.313E-03</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>6.178E-05</td>
<td>5.234E-05</td>
<td>2.188E-05</td>
<td>5.116E-05</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>kg</td>
<td>2.796E-13</td>
<td>2.932E-13</td>
<td>2.563E-13</td>
<td>1.471E-14</td>
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<tr>
<td>Ethane (HC2:15)</td>
<td>kg</td>
<td>5.024E-04</td>
<td>9.131E-04</td>
<td>1.612E-04</td>
<td>4.598E-06</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>4.693E-11</td>
<td>1.334E-11</td>
<td>1.623E-11</td>
<td>1.373E-11</td>
</tr>
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<td>kg</td>
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<td>1.623E-16</td>
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</tr>
<tr>
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<td>kg</td>
<td>4.074E-04</td>
<td>1.034E-04</td>
<td>8.373E-05</td>
<td>1.373E-11</td>
</tr>
<tr>
<td>NYMOX</td>
<td>kg</td>
<td>1.646E-05</td>
<td>1.091E-04</td>
<td>1.176E-04</td>
<td>1.373E-11</td>
</tr>
<tr>
<td>Phosphorus (in air)</td>
<td>kg</td>
<td>8.056E-04</td>
<td>2.623E-04</td>
<td>3.053E-04</td>
<td>1.373E-11</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>8.056E-04</td>
<td>2.623E-04</td>
<td>3.053E-04</td>
<td>1.373E-11</td>
</tr>
</tbody>
</table>

### Transport processes

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Flight transport</th>
<th>Rail transport</th>
<th>Ship transport</th>
<th>Truck transport</th>
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</thead>
<tbody>
<tr>
<td>Ammonia (in air)</td>
<td>kg</td>
<td>2.983E-06</td>
<td>7.046E-06</td>
<td>5.107E-05</td>
<td>2.386E-06</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.099E-00</td>
<td>3.274E-01</td>
<td>1.048E-01</td>
<td>1.342E-01</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>1.315E-03</td>
<td>1.138E-04</td>
<td>2.525E-04</td>
<td>3.010E-04</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>kg</td>
<td>1.166E-05</td>
<td>1.022E-05</td>
<td>2.622E-05</td>
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</tr>
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<td>Ethane (HC2:15)</td>
<td>kg</td>
<td>1.431E-13</td>
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<td>6.123E-14</td>
<td>6.980E-14</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>6.030E-04</td>
<td>5.756E-05</td>
<td>7.831E-06</td>
<td>2.001E-04</td>
</tr>
<tr>
<td>Methane (C2:13)</td>
<td>kg</td>
<td>1.500E-08</td>
<td>1.556E-10</td>
<td>9.518E-11</td>
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</tr>
<tr>
<td>NYMOX</td>
<td>kg</td>
<td>6.070E-04</td>
<td>2.179E-05</td>
<td>1.018E-05</td>
<td>1.540E-04</td>
</tr>
<tr>
<td>Phosphorus (in air)</td>
<td>kg</td>
<td>1.883E-05</td>
<td>1.941E-05</td>
<td>1.321E-05</td>
<td>1.707E-05</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>3.562E-03</td>
<td>9.705E-04</td>
<td>1.353E-04</td>
<td>1.640E-04</td>
</tr>
</tbody>
</table>

### End-of-life processes

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Waste incineration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (in air)</td>
<td>kg</td>
<td>1.099E-05</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.224E-00</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>2.980E-04</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>kg</td>
<td>1.315E-03</td>
</tr>
<tr>
<td>Ethane (HC2:15)</td>
<td>kg</td>
<td>2.290E-14</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>5.119E-05</td>
</tr>
<tr>
<td>Methane (C2:13)</td>
<td>kg</td>
<td>3.420E-15</td>
</tr>
<tr>
<td>Methane (C2:13)</td>
<td>kg</td>
<td>1.310E-10</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
<td>4.989E-04</td>
</tr>
<tr>
<td>NYMOX</td>
<td>kg</td>
<td>7.610E-05</td>
</tr>
<tr>
<td>Phosphorus (in air)</td>
<td>kg</td>
<td>8.950E-07</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>4.660E-05</td>
</tr>
</tbody>
</table>
### Life Cycle inventory results

#### Example - Check the formulas and see how we have done

**Material, energy and transportation**

To calculate the inventory results you should multiply your input data with each corresponding Unit process array (see "Unit process" worksheet). You need to use the S-sign to lock the cell from the "Product data" page.

**End of life treatment**

Here we need to calculate the emissions from the end-treatments but also calculate avoided production from the generation of heat and electricity. The example of recycling was the amount of electricity used for recycling and the multiplies with an assumed electricity process (in this case I have assumed recycling in China). For the avoided processes we subtract the emissions since these are assumed to be avoided when we incorporate.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Aluminium</th>
<th>Polypropylene (PP)</th>
<th>Steel</th>
<th>Rubber</th>
<th>Polyester (PET)</th>
<th>Ship transport</th>
<th>Woven cot</th>
<th>Recycling aluminium</th>
<th>Recycling steel</th>
<th>Incineration</th>
<th>Avoided electricity</th>
<th>Avoided heat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (as NH3)</td>
<td>g</td>
<td>0.001817849</td>
<td>2.307911-07</td>
<td>9.455478-05</td>
<td>0.00016074</td>
<td>0.0000229</td>
<td>0.000204421</td>
<td>0.000787</td>
<td>5.505388-06</td>
<td>1.661248-06</td>
<td>0.00004736</td>
<td>4.177946-06</td>
<td>0.00011574</td>
<td>0.00076024</td>
</tr>
<tr>
<td>Carbon dioxide, CO₂</td>
<td>g</td>
<td>42.98255133</td>
<td>2.50813333</td>
<td>1.48671081</td>
<td>0.000459</td>
<td>2.09</td>
<td>2.03354078</td>
<td>19.3</td>
<td>1.14539978</td>
<td>0.41907384</td>
<td>5.3768</td>
<td>0.27751584</td>
<td>0.12190032</td>
<td>102.135938</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>g</td>
<td>0.647394331</td>
<td>0.00912733</td>
<td>0.05172</td>
<td>0.059785</td>
<td>0.00152</td>
<td>0.0049314</td>
<td>0.0492</td>
<td>0.00022004</td>
<td>8.049389-05</td>
<td>0.00122</td>
<td>0.00001268</td>
<td>0.00024506</td>
<td>0.73385590</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>g</td>
<td>0.001757388</td>
<td>1.0644-07</td>
<td>1.223186-05</td>
<td>0.0002242</td>
<td>0.0000243</td>
<td>5.3702-05</td>
<td>0.00299</td>
<td>3.184318-05</td>
<td>4.909929-06</td>
<td>0.00095864</td>
<td>-0.960939-05</td>
<td>-0.00417605</td>
<td>0.804971260</td>
</tr>
<tr>
<td>Methane</td>
<td>g</td>
<td>0.108372707</td>
<td>0.01772737</td>
<td>0.001604</td>
<td>-0.014316</td>
<td>2.931-09</td>
<td>0.0015268</td>
<td>3.16-08</td>
<td>0.007396444</td>
<td>0.00232035</td>
<td>0.00098251</td>
<td>0.000214439</td>
<td>0.164912811</td>
<td></td>
</tr>
<tr>
<td>Methane (C₂H₆)</td>
<td>g</td>
<td>2.9666469-07</td>
<td>1.80348611</td>
<td>1.847989-09</td>
<td>9.8045-13</td>
<td>2.564-12</td>
<td>1.856097-08</td>
<td>3.28-07</td>
<td>5.35635-10</td>
<td>3.95947-10</td>
<td>1.504E-14</td>
<td>-3.02271-10</td>
<td>-1.66907-10</td>
<td>0.446088-07</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>g</td>
<td>0.139962972</td>
<td>0.004942951</td>
<td>0.00327949</td>
<td>0.009006</td>
<td>0.00615</td>
<td>0.27073847</td>
<td>0.0539</td>
<td>0.00427084</td>
<td>0.001563962</td>
<td>0.00121536</td>
<td>0.000501813</td>
<td>0.000945297</td>
<td>0.274693348</td>
</tr>
<tr>
<td>N₂O</td>
<td>g</td>
<td>0.016733728</td>
<td>0.005357482</td>
<td>0.00031177</td>
<td>0.0072777</td>
<td>0.00532</td>
<td>0.00348848</td>
<td>0.00534</td>
<td>3.580720-05</td>
<td>1.398468-05</td>
<td>0.00133480</td>
<td>4.236456-05</td>
<td>0.00021372</td>
<td>0.042330412</td>
</tr>
<tr>
<td>Phosphorus (as P)</td>
<td>g</td>
<td>7.210095-07</td>
<td>4.793941-09</td>
<td>7.479262-08</td>
<td>1.74096-07</td>
<td>0.000001052</td>
<td>2.573920-08</td>
<td>2.791-06</td>
<td>1.130658-08</td>
<td>4.648235-09</td>
<td>0.000009398</td>
<td>-3.237085-07</td>
<td>-1.38797-05</td>
<td>-3.11272-05</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>g</td>
<td>0.252814204</td>
<td>0.005681388</td>
<td>0.000328119</td>
<td>0.012958</td>
<td>0.00979</td>
<td>0.26385457</td>
<td>0.0949</td>
<td>0.00035928</td>
<td>0.003621807</td>
<td>0.00020204</td>
<td>0.000036352</td>
<td>0.004264193</td>
<td>0.439229031</td>
</tr>
</tbody>
</table>
Characterization factors for EPD-method
For more information about the EPD-method please check the following home page: http://www.environext.com/en/The-EPD-system/Programme-instructions/

<table>
<thead>
<tr>
<th>Substance</th>
<th>Global warming (GWP100) [kg CO₂ eq / kg]</th>
<th>Ozone layer depletion (ODP) [kg CFC-11 eq / kg]</th>
<th>Photochemical oxidation [kg CH₄ eq / kg]</th>
<th>Acidification [kg SO₂ eq / kg]</th>
<th>Eutrophication [kg PO₄³⁻ eq / kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.35</td>
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<tr>
<td>Carbon dioxide</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>296</td>
</tr>
<tr>
<td>Ethane (C₂H₆)</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<tr>
<td>Methane</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Methane (C₂H₆)</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>NMOC</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>0.048</td>
<td>0.048</td>
<td>0.048</td>
<td>0.048</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Normalisation factors

<table>
<thead>
<tr>
<th>Global warming (GWP100) [kg CO₂ eq / pers/yr]</th>
<th>Ozone layer depletion (ODP) [kg CFC-11 eq / pers/yr]</th>
<th>Photochemical oxidation [kg CH₄ eq / pers/yr]</th>
<th>Acidification [kg SO₂ eq / pers/yr]</th>
<th>Eutrophication [kg PO₄³⁻ eq / pers/yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalisation factors</td>
<td>11216</td>
<td>0.021</td>
<td>53.1</td>
<td>33.8</td>
</tr>
</tbody>
</table>

Environmental Impact Assessment Results

Example - Check the formulas to see how we have done

Environmental impact assessment
In order to calculate the contribution of your product to the different impact categories you will need to multiply your results from the inventory with the characterisation factors in the worksheet with that name. In the example of Global Warming below we have used the function SUMPRODUCT (or PRODUCTSUMMA (if you use Swedish Excel) to multiply the arrays Total example "Inventory results" 6 to 117) and the characterization factors for global warming ("Characterisation factors" 86 to 817). The impact assessment could be done for each process, life cycle phases well as the total.

<table>
<thead>
<tr>
<th>Global warming (GWP100) [kg CO₂ eq / kg]</th>
<th>Ozone layer depletion (ODP) [kg CFC-11 eq / kg]</th>
<th>Photochemical oxidation [kg CH₄ eq / kg]</th>
<th>Acidification [kg SO₂ eq / kg]</th>
<th>Eutrophication [kg PO₄³⁻ eq / kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>108,346,717</td>
<td>1,965,488.06</td>
<td>0.075593677</td>
<td>0.637054408</td>
</tr>
<tr>
<td>Normalized values</td>
<td>0.98617%</td>
<td>0.00936%</td>
<td>0.14236%</td>
<td>1.85190%</td>
</tr>
</tbody>
</table>
## Appendix 5 – LCA Data PSS Model Stroller

### Life Cycle Inventory Data for the Product

**Example of how to put in your product data and assumptions**

Check under "Unit Processes" to see which processes that are available to you. Make the best assumption from the list. If your specific materials are not listed.

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount per FU</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine</td>
<td>1.4</td>
<td>kg</td>
</tr>
<tr>
<td>Steel</td>
<td>5.3</td>
<td>kg</td>
</tr>
<tr>
<td>Rubber</td>
<td>1.9</td>
<td>kg</td>
</tr>
<tr>
<td>Glass fibre</td>
<td>1.5</td>
<td>kg</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0</td>
<td>kg</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>2</td>
<td>kg</td>
</tr>
<tr>
<td>Energy during use phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric energy (CENTREL)</td>
<td></td>
<td>MJ</td>
</tr>
</tbody>
</table>

**Transportation**

- Distance prod. to resale: 15000 km
- Weight transported: 13 kg
- Ship transport: 195 tonkm

Transportation needs to be turned into the unit "tonkm" (mass × distance) in order to calculate the inventory results.

In order to simplify the LCA somewhat we need to make some assumptions regarding end-of-life treatments. We propose (you can test these assumptions) that you use closed-loop recycling with a 50% recycling rate for the metals and 100% incineration for the plastics and packaging waste. When you calculate the end-of-life treatments you can use the following values for electricity use in the recycling and generated energy from incineration.

<table>
<thead>
<tr>
<th>Material</th>
<th>Electricity used in recycling (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling, Steel</td>
<td>1,512</td>
</tr>
<tr>
<td>Recycling, Aluminium</td>
<td>0.6264</td>
</tr>
<tr>
<td>Recycling Copper</td>
<td>0.0644/652</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incinerated waste</th>
<th>Generated electricity (MJ/kg)</th>
<th>Generated heat (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.326</td>
<td>11.934</td>
</tr>
</tbody>
</table>

### Example end-of-life treatment

<table>
<thead>
<tr>
<th>Treatment rate</th>
<th>Amount (kg)</th>
<th>Used electricity (MJ)</th>
<th>Generated elec. (MJ)</th>
<th>Generated heat (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled aluminium</td>
<td>100%</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Incineration</td>
<td>0%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recycled steel</td>
<td>100%</td>
<td>5.3</td>
<td>8.0136</td>
<td>0</td>
</tr>
</tbody>
</table>

 Proceed to "Inventory results" to see an example on how these can be calculated.
### Life Cycle Inventory Data for Unit Processes

**These are simplified aggregated data for emissions from cradle-to-gate processes.**

The emissions presented below are just a selection of the emissions in the full version.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Plastic Processes (substance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance</td>
<td>Unit</td>
</tr>
<tr>
<td>Ammonium (as salt)</td>
<td>kg</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>kg</td>
</tr>
<tr>
<td>Ethane (HCEF-140)</td>
<td>kg</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
</tr>
<tr>
<td>Methane (EC-11)</td>
<td>kg</td>
</tr>
<tr>
<td>Methane (Halon 1301)</td>
<td>kg</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
</tr>
<tr>
<td>NVOC</td>
<td>kg</td>
</tr>
<tr>
<td>Phosphorus (as P)</td>
<td>kg</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
</tr>
</tbody>
</table>

### Energy and heat

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Electric energy (CENTRAL)</th>
<th>Electric energy (Chinese electricity mix)</th>
<th>Electric energy (NORDIC)</th>
<th>Heat production from biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium (as salt)</td>
<td>kg</td>
<td>8.47E-07</td>
<td>1.32E-06</td>
<td>1.05E-06</td>
<td>2.12E-06</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>2.24E+01</td>
<td>2.71E+01</td>
<td>4.75E+02</td>
<td>2.32E+03</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>6.17E+05</td>
<td>5.22E+05</td>
<td>2.78E+05</td>
<td>5.79E+05</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>kg</td>
<td>3.29E+05</td>
<td>3.42E+05</td>
<td>3.79E+05</td>
<td>2.83E+05</td>
</tr>
<tr>
<td>Ethane (HCEF-140)</td>
<td>kg</td>
<td>2.37E+13</td>
<td>2.93E+13</td>
<td>2.56E+13</td>
<td>1.47E+14</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>5.20E+03</td>
<td>1.93E+03</td>
<td>1.61E+04</td>
<td>4.59E+06</td>
</tr>
<tr>
<td>Methane (EC-11)</td>
<td>kg</td>
<td>4.49E+16</td>
<td>1.33E+16</td>
<td>1.29E+16</td>
<td>1.26E+16</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
<td>4.03E+04</td>
<td>1.46E+03</td>
<td>8.53E+03</td>
<td>1.32E+04</td>
</tr>
<tr>
<td>NVOC</td>
<td>kg</td>
<td>1.57E+05</td>
<td>9.29E+04</td>
<td>2.62E+05</td>
<td>4.23E+05</td>
</tr>
<tr>
<td>Phosphorus (as P)</td>
<td>kg</td>
<td>3.16E+08</td>
<td>2.67E+09</td>
<td>5.37E+08</td>
<td>3.54E+07</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>8.56E+06</td>
<td>2.63E+06</td>
<td>1.03E+06</td>
<td>8.12E+06</td>
</tr>
</tbody>
</table>

### Transport processes

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Flight transport</th>
<th>Rail transport</th>
<th>Ship transport</th>
<th>Truck transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium (as salt)</td>
<td>kg</td>
<td>2.29E+03</td>
<td>9.02E+07</td>
<td>1.04E+06</td>
<td>2.38E+08</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.06E+00</td>
<td>3.27E+02</td>
<td>1.04E+02</td>
<td>1.47E+02</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>3.13E+03</td>
<td>1.13E+04</td>
<td>2.54E+02</td>
<td>3.01E+04</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>kg</td>
<td>1.16E+05</td>
<td>1.02E+05</td>
<td>6.22E+02</td>
<td>6.12E+06</td>
</tr>
<tr>
<td>Ethane (HCEF-140)</td>
<td>kg</td>
<td>1.63E+13</td>
<td>6.13E+12</td>
<td>1.24E+15</td>
<td>6.90E+14</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>6.03E+04</td>
<td>5.75E+05</td>
<td>7.83E+06</td>
<td>2.00E+04</td>
</tr>
<tr>
<td>Methane (EC-11)</td>
<td>kg</td>
<td>1.50E+08</td>
<td>1.56E+10</td>
<td>9.51E+11</td>
<td>1.27E+09</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
<td>2.16E+15</td>
<td>2.60E+16</td>
<td>1.06E+17</td>
<td>1.33E+14</td>
</tr>
<tr>
<td>NVOC</td>
<td>kg</td>
<td>6.07E+04</td>
<td>2.19E+05</td>
<td>1.01E+05</td>
<td>1.54E+04</td>
</tr>
<tr>
<td>Phosphorus (as P)</td>
<td>kg</td>
<td>1.98E+03</td>
<td>1.94E+03</td>
<td>1.09E+03</td>
<td>1.10E+03</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>1.56E+03</td>
<td>9.70E+04</td>
<td>1.53E+04</td>
<td>1.64E+04</td>
</tr>
</tbody>
</table>

### End-of-life processes

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>Disposal of plastics to municipal incineration plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium (as salt)</td>
<td>kg</td>
<td>1.06E+05</td>
</tr>
<tr>
<td>Carbon dioxide, fossil</td>
<td>kg</td>
<td>1.22E+00</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>kg</td>
<td>2.60E+04</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>kg</td>
<td>1.36E+05</td>
</tr>
<tr>
<td>Ethane (HCEF-140)</td>
<td>kg</td>
<td>2.28E+14</td>
</tr>
<tr>
<td>Methane</td>
<td>kg</td>
<td>5.11E+05</td>
</tr>
<tr>
<td>Methane (EC-11)</td>
<td>kg</td>
<td>3.42E+15</td>
</tr>
<tr>
<td>Methane (Halon 1301)</td>
<td>kg</td>
<td>1.31E+10</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>kg</td>
<td>4.90E+04</td>
</tr>
<tr>
<td>NVOC</td>
<td>kg</td>
<td>7.61E+05</td>
</tr>
<tr>
<td>Phosphorus (as P)</td>
<td>kg</td>
<td>8.95E+07</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>kg</td>
<td>4.66E+05</td>
</tr>
<tr>
<td>Name</td>
<td>Age</td>
<td>Gender</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>John</td>
<td>25</td>
<td>Male</td>
</tr>
<tr>
<td>Mary</td>
<td>30</td>
<td>Female</td>
</tr>
<tr>
<td>Tom</td>
<td>35</td>
<td>Male</td>
</tr>
</tbody>
</table>

**APPENDICES**

*Example - Check the formula and how we have done the calculation.*

*Final note on the appendix comments.*
Characterization factors for EPD method

For more information about the EPD method please check the following homepage:


<table>
<thead>
<tr>
<th>Substance</th>
<th>Global warming (GWP100) [kg CO2-eq / kg]</th>
<th>Ozone layer depletion (ODD) [kg CFC-11 eq / kg]</th>
<th>Photochemical oxidation [kg C1H2 / kg]</th>
<th>Acidification [kg SO2 eq / kg]</th>
<th>Eutrophication [kg PO4 eq / kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (to air)</td>
<td>1.0</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>1</td>
<td>0.027</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>1,53</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>298</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethane [C2H6]</td>
<td>23</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane (CFC-11)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane (halon 1301)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.028</td>
<td>0.5</td>
<td>0.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogenic oxides</td>
<td>0.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus (to air)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>0.048</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Normalisation factors

| Global warming (GWP100) [kg CO2-eq / pers/year] | Ozone layer depletion (ODD) [kg CFC-11 eq / pers/year] | Photochemical oxidation [kg C1H2 / pers/year] | Acidification [kg SO2 eq / pers/year] | Eutrophication [kg PO4 eq / pers/year] |
|------------------------------------------------|
| Normalisation factor                          | 0.634                                                  | 53.3                                           | 34.4                                 | 0.014                               |

Environmental impact Assessment Results

Example - Check the formulas to see how we have done

In order to calculate the contribution of your product to the different impact categories you will need to multiply your results from the inventory with the characterization factors in the worksheet with that name. In the example of Global Warming below we have used the function SUMPRODUCT (or PRODUKTSAMMA, if you use Swedish Excel) to multiply the arrays. Total example ("Inventory results" L6 to L17) and the characterization factors for global warming ("Characterisation factors" B6 to B17). The impact assessment could be done for each process, life cycle phase as well as the total.

<table>
<thead>
<tr>
<th>Global warming (GWP100) [kg CO2-eq / kg]</th>
<th>Ozone layer depletion (ODD) [kg CFC-11 eq / kg]</th>
<th>Photochemical oxidation [kg C1H2 / kg]</th>
<th>Acidification [kg SO2 eq / kg]</th>
<th>Eutrophication [kg PO4 eq / kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>27,181,525.03</td>
<td>1,241,886.06</td>
<td>0.027</td>
<td>0.174</td>
</tr>
<tr>
<td>Normalised values</td>
<td>0.24239%</td>
<td>0.008591%</td>
<td>0.005148%</td>
<td>0.000147</td>
</tr>
</tbody>
</table>

Appendix 6 - Prototype Process Pictures
Appendix 7 – Raw Data from Customer Survey

To access the raw data, click on the link: https://forms.gle/WLt3JgcpPgEzBZ336
Appendix 8 – Wireframes for website prototype
How it works & price example

your close by Service Hub

living within the planetary boundaries

where ever you live

whatever the age

You are here, great choice to consider Ease Stroller

Grocery Delivery

2000 SEK / month (confinable)

Car Pool + Child insurance

650 SEK / month + miles fee

Stroller with growth plan

250 SEK / month (first month free)

2900 SEK / month*

Where do you live?

Enter address

MAP OF STOCKHOLM

APPENDICES
Tell us a little bit more about your family

How many children do you have? 1 and how old are they (month)? 0

How do you and your family commute or like to commute? Select down below:

- Car
- Bike
- Public transportation
- Run
- Walk

Design your stroller

Choose one of the five colors or pick your own color on the color wheel, we print the colors on the paper board and send it to your closes Service Hub, who install it for you. The carrycot is water repellent and breaths in a natural way, to make sure your child gets the best possible experience. After you are done using the carrycot, just return it to your Service Hub and we recycle it for you and upgrades the stroller with a new carrycot adopted for your child’s age.
Appendix 9 – Recordings

Interview recordings available upon request, email gust086@student.liu.se to get hold of the material.