Product development of an ergonomic and sustainable iron designed for its context

Advanced Development SDA at Electrolux

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Abstract

This report presents the process of a product development of an iron with technically improved functions, an ergonomic evaluation with suggestion of improvement and a design process of an iron designed for the context it will be used in. The master thesis was written by two master students from Industrial Engineering and Management department of The Royal Institute of Technology at the Advanced Development department at Electrolux.

A literature study was performed using KTH search tool Primo for articles of scientific height along with a state of the art and market analysis and a patent search. After the literature study the process moved over to an investigation of different ironing methods inspired by the standard IEC 60311. The result was used in combination with literature study to develop technical prototypes which concluded in one final product.

A user study was completed with a survey, observation and deeper interviews to understand users’ needs which resulted in insights, personas and customer journeys. The user study findings were thereafter analysed and categorised into a list of opportunity of improvements, function analysis and list of requirements. These were used as tools when continuing with idea generation and prototype development. The prototypes resulted in a technical solution and an ergonomic study focusing on the angle of the handle. User tests were completed within both areas which resulted in recommendations and suggestions based on user needs.

A design concept was developed alongside the prototyping process. This process consisted of sketches, models and a final design based on three mood boards describing Electrolux, the context the iron is used and design guidelines for the new iron.

The final product resulted in an ergonomic and sustainable iron with a design which blends with the interior of a home. The handle was suggested to be 30° in relation to the soleplate to enable a relaxing posture for the wrist and body.

**Keywords:** Iron, product development, ergonomic, user study, design, prototype
Sammanfattning

Denna rapport presenterar en produktutvecklingsprocess av ett strykjärn med tekniskt förbättrade funktioner, en ergonomisk utvärdering med förslag på förbättring och en designprocess av ett strykjärn designat för det sammanhang det används i. Examensarbetet slutfördes av två master studenter från Kungliga Tekniska Högskolan, KTH, för Primärutvecklingsavdelningen på Electrolux.

En litteraturstudie utfördes med hjälp av KTHs sökverktyg Primo för artiklar av vetenskaplig höjd tillsammans med en State of the Art, marknadsanalys och en patentsökning. Efter litteraturstudien fortsatte processen med en undersökning av olika strykningsmetoder med hjälp av standarden IEC 60311. Resultatet användes i kombination med litteraturstudien vid utveckling av tekniska prototyper.


Ett designkoncept utvecklades parallellt med de två prototypprocesserna. Denna process bestod av skisser, modeller och en slutlig design baserad på tre MoodBoards, en som beskriver Electrolux, en för omgivningen som strykjärnet används och en med design riktlinjer för det nya strykjärnet.
Slutprodukten resulterade i ett ergonomiskt och hållbart strykjärn med en design som passar in i ett hem. Handtaget föreslås vara 30° mot stryksulan för att möjliggöra en mer avslappnande hållning för handleden och kroppen.

**Nyckelord:** Strykjärn, produktutveckling, ergonomi, användarstudier, design, prototyp
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1. Introduction

This introduction presents the background of ironing and the values of the Electrolux who has been the case company of this master thesis. The chapter then moves on to describing background and Electrolux, the purpose, the chosen method, detailed schedule and delimitations.

1.1 Background

This master thesis project aimed to improve the method of ironing. The main purpose of ironing is to reduce creases on fabric. Creases consists of fibres that have gotten fixed in a tangled position and the iron needs to unravel them. An iron reduces creases by adding heat, moisture and press which untangles the fibres and creates the desired result.

Several methods can be used to iron. Most commonly used are steam and dry irons but there are also alternative methods as steamers and smart ironing boards. Within the fabric and clothing industry there are more refined methods and machines which also are created for a faster product cycle. This thesis will focus on the ironing methods for domestic use and the solution should be adapted to the environment of the end user.

Despite the fast technological changes and developments in today's community with innovations such as Internet of Things (IoT Sweden, 2017), the ironing methods have almost looked the same and used the same functions since the origin of its development. Only smaller configurations have been added to the iron since the steam function was introduced 1934 (Allt om Vetenskap, 2004). The handle of the iron has also changed its angle through time and the design has shifted from being a product made out of exclusive materials into a cleaning product with streamline shape and plastic components.

There was therefore an interest in investigating whether there can be made any improvements to the ways of ironing. This project should also challenge the ergonomics and design of the iron and through that develop an iron that is designed for all users.

1.2 Values of Electrolux

This master thesis was carried out at Electrolux. Their purpose is to "Shape living for the better" and create best-in-class consumer experience through always improving, creating better experiences and act sustainable. The company is a global leader within home appliances and sell 60 million products in more than 150 markets every year. The products of Electrolux are carefully developed with a base in extensive consumer insights and in collaboration with professional users. Electrolux has a strong sustainable focus with the aim of offering products that improve their users' everyday life and at the same time decreasing used energy, water and material resources (Electrolux, 2018).

This master thesis was performed at the Advanced Development department of Home care and Small Domestic Appliances. The department focus on developing and investigating new technology before it is implemented into the product development process.
1.3 Purpose

The purpose of this master thesis was to generate a solution that solved challenges within ironing. The solution was developed utilizing research, evaluation of existing ironing methods, tests and user studies. The solution consists of three areas: technical, ergonomics and design. The technical solution improved irons’ performance, the ergonomics improved the usability and the design improved user experience. All these areas resulted in a product that was in line with Electrolux’s values.

The project deliverables were a functional prototype demonstrating the technical solution, suggestion for how the ergonomic and design suggestion could be visualised and a written report stating the process and results.

1.4 Method description: The double diamond process

The design development process followed the double diamond process, (DXD, 2016). This process was considered appropriate as it is promoting having two diverging- and converging phases that enables for more opportunities to be discovered. The diamond process visualizes the amount of work put into the project by pointing out that the work effort is both high at the start of the project as at the end. The diamond process also promotes several iterations when prototyping which was considered needed when creating a model that has to be functional, see figure 1.

![Figure 1. An illustration of the diamond (DXD, 2016).](image-url)

The phases this master thesis project was guided by was:

1.4.1 Phase 1 Discover

Primary research focused on the literature study and investigation of present products and their functions. Articles were gathered using the KTH library Primo (KTH library, 2015)
search tool, patent search using espacenet.com (Espacenet, 2017) and investigation was conducted using IEC 60311.

In order to give the work more substance the secondary research focused on the use of the products and users' interaction with the product. Here the idea was to identify how the product was used, if they are used as they are intended to and to find areas of opportunity to come up with improvements. This was done using observations, interviews and surveys.

The result from primary and secondary research was combined in to one final prototype and several less advanced ones along the iterative process.

1.4.2 Phase 2 Define

The generated data from the primary and secondary research were compiled and converged with the aim of generating insights and opportunity areas that needed improvement. This phase generated measurable data that worked as a foundation for the iterations. The compiled data was also configured into a specification of requirements.

1.4.3 Phase 3 Develop

This phase can also be called the ideation phase. Here the diverging consisted of idea generating methods based on the results from the previous phases. It was desired to generate as many ideas and concepts as possible in order to move over to the second part of the phase, evaluation. The evaluation process resulted in several ideas to move forward with to the deliver phase where prototypes were created.

1.4.4 Phase 4 Deliver

This phase was an iterative process consisting of three steps: Build prototype, Test and Analyse and the last step to Iterate. The prototypes/mock-ups was after around two to three iterations converge down to the last and final functional prototype which leads to phase B where to results was documented, analysed, discussed and presented.

1.5 Detailed schedule

A time plan was created using excel. The activities have estimated time in days and the activities are gathered into phases of the Double diamond process to clarify how long the different phases would take. At the end of each phase the days were gathered into weeks and the time plan ended with days and weeks left. The time plan was organised so that there was three weeks left in case unexpected event would occur which delayed the schedule, see Appendix A. Dates were not used since the work was conducted in a total of 20 weeks with no holiday days included.

Since the project was conducted by two students the number of weeks can be doubled to a total of 40 weeks. Many of the steps in the process was conducted together, by the means of
being more efficient and for both to learn by the process and gained knowledge during tests and user study. When the process was in the literature study phase and some of the prototyping phase, the work was divided to avoid wasting time by doing double work. The same went for the writing of the report and documentation throughout the process.

By the end of the process the three extra weeks had been added to the prototyping process and an extra week was added to phase B for finalising the report and rendering of pictures. The time plan helped the process moving forward and guided when decision had to be made and test finished.

1.6 Delimitations

The focus of this master thesis was to create a device that successfully removed creases through improving the iron within three areas: technical, ergonomics and design.

Delimitations made:

- Only include a limited part of the users’ process flow. The part of the process that was chosen was when the fabrics had received creases and ironing was used to remove the creases. No work was therefore performed on developing a method of reducing the creases before the process of ironing, for example to develop crease resistant clothes.
- Focus on an ironing product. Delimitation was made regarding what ironing product the creases was removed with. The project delivery was to develop an iron and no improvements was therefore made to garment steamers, steam cabinets or iron boards.
- The developed iron should only be used for domestic use and focus has therefore not been to solve the problems for professionals within ironing.
- Time was limited to a 20-week project and the product was therefore not evaluated for production. The presented final product was therefore only conceptual suggestions for the technical, ergonomic and design solution and not the final outcome including choice of material.
2. Literature study

The literature study has been performed using the KTH search tool Primo that offers scientific articles online (KTH library, 2015). A state of the art was conducted to learn what products and solutions were developed to establish the competition and find areas of improvement. Patents have been analysed using Espacenet (Espacenet, 2017), with the purpose of determine what has been done and to find inspiration for areas that has not been investigated.

2.1 Articles with scientific height

A research of articles with scientific height was performed. The research commenced with the basic components needed to iron with explanation of fabric fibres and moisture which continues with function and design history of ironing and ergonomics in ironing.

Some sections have been removed due to confidentiality.

2.1.1 Ironing – heat, moisture, pressure and vacuum

According to Rajkishore Nayak and Rajiv Padhye (2015, p.398) pressure, heat, moisture and vacuum for cooling is required in order to gain the optimum performance of good quality pressing, also called ironing (Nayak, Rajkishore; Padhye, Rajiv, 2015).

Most irons today come with the abilities to use heat, pressure, steam and water spray. When ironing, the pressure is mostly created by the users when pressing the iron against the fabric, but some irons are heavier than others which help the pressing procedure. Heat can be used to relax the fibres and moisture facilitate the transportation of heat. Steam is a moisture that also includes heat. Steam is created in the iron soleplate and then applied through holes in the soleplate. The steam is therefore applied directly underneath the soleplate while a spray of water applies the water in front of the iron. Vacuuming can be used at the end of the ironing process. The air from vacuuming extracts the remaining moisture and heat and draws cool air through the fibres that helps to fixates the fabric (Nayak, Rajkishore; Padhye, Rajiv, 2015). The technique of using vacuuming is mostly applied in the fabric and clothing industry and is not offered in todays’ irons built for domestic use. The vacuuming function can be found in advanced iron boards for domestic use.

By the end of the ironing process it is important that moisture in the fabric has dried up and that the fabric has cooled down to avoid new creases or old creases to recover (WO Patent No.2004/085732, 2004).

Fabric fibres

In order to determine what is required to achieve the optimum ironing result, an understanding of what creases are and what causes them was needed.
Fabrics consist of fibres that is either natural or synthetic. Creases consist of fibres that have been fixated in a tangled position and these needs to be untangled and arranged in a straight composition in order for the crease to disappear. The creases are usually caused by change of temperature, humidity or pressure. The fibres are connected to each other by intra-and intermolecular attractions that fixates the fibres to the given position. These connections need to be weakened in order for the fibres to move freely and enable rearrangement, (Liang et al, 2017, page 1). The main method for weakening these bonds are by using heat.

**Heat**

Heat is needed to reach the temperature of which the fibres are able to move from their fixed position, which is their glass temperature, Tg. All non-crystalline solid without a melting point have a Tg (CES EduPack, 2018). The bonds between the fibres gain enough energy to relax when the Tg of the material has been reached. The energy allows the fibres to be more flexible and they loosen from their fixed, wrinkly state and restored to their original straight position. They then need to be cooled down to a temperature under Tg in order for the fibres to be fixed in that position (Liang et al, 2017).

The temperature of Tg differs between fabrics. If wrong temperature is chosen, the fabric can end up shrinking, degradation or lose its colour (Nayak, Rajkishore; Padhye, Rajiv, 2015). To avoid choosing the wrong temperature most irons and cloth's labels have indications in dots from one dot up till three. These dots represent the correct temperature and amount of steam for the chosen fabric.

**Moisture**

Moisture is used to accelerate and improve the ironing results. The fibres swells when absorbing the water which helps weakening the intermolecular bonds between the fibres. The weakened bonds lowers the glass transitioning temperature, Tg. The moisture therefore lowers the heat needed to reach Tg and relax the fibres (Bryant, G.M. and Walter, A.T., 1959). One should be careful to use too much moisture though since this may cause some fabrics to shrink or colour to bleed (Fergusson, S. MacA., 2015, p.398).

Most irons are equipped with steam and a water spray in the front. The water spray is used to give extra moisture and help the swelling of the fibres. A separate water spray can also be used for the same purpose.

The duration of the ironing is also said to affect the result since more steam would be transferred onto the fabric the longer the ironing soleplate, which applies the steam, stays in one place (Liang et al, 2016). The recommendation is to constantly move the iron and some irons indicates when the iron has stayed still for too long.

**Steam**

Steam includes moisture and heat. There are ironing products that only use steam to reduce creases, for example garment steamers. Steam in irons is created when water from the tank drips in to a channel located within the soleplate, called the steam chamber. The soleplate is
warm due to heating elements which makes the water evaporate and the steam escapes the soleplate through holes underneath (Tefal, 2016).

***Lime scale***

A common problem with irons is lime scale which is created on the inside of the iron soleplate. Lime scale is created when water is heated. The increasing temperature extracts the calcium carbonate from the solution. Other factors that affects the extraction is whether the water is "hard" and what pH it has. "Hard water" involves extra magnesium and calcium ions and has a basic pH value, (Västvatten, 2018). The lime scale problem occurs when the lime scale leaves the soleplate and covers the fabric which happens when the pressure used to apply steam loses the lime scale from the soleplate's chamber walls. The lime scale can also affect the steam distribution and as the particles can block the passage ways for the steam and reduce the flow (Tefal, 2016).

***Pressing***

The positioning of the handle of an iron is vital in order for the iron's centre of gravity (Glenn research centre, 2015) to be in line with the hand and create a homogenous pressing of the fabric. A moment is created when the user pushes the iron and the handle is not positioned straight above the centre of the iron's gravity. The moment makes the iron tip which in turn results in uneven pressing. If the load is not transferred evenly onto the fabric, the pressing will not be homogenous across the soleplate and give an uneven result since the heat transfer is based upon the pressing.

A heavy iron does not need the same amount of pressing vertically as a light iron and the force can then mainly be applied horizontally to move the iron forward. However, if the iron is light then the user must both move the iron horizontal while pressing the iron vertical to conduct pressing. It is therefore desired to have a handle that transfers a load both horizontally and vertically when having a light iron.

The shape of the soleplate is also a factor that affects the pressing result. Electrolux 5safety has for example been fitted with a soleplate that has an ending that tilts upwards to avoid having fabric stuck underneath the soleplate when moving it backwards.

The friction coefficient plays an important role in how well the soleplate glides across the fabric. It is desired to have a low coefficient to reduce the load needed for the user when moving the iron across the fabric (Tefal, 2016).

### 2.1.2 Ergonomics

Ergonomics is about considering and adjusting the work for completing a task by avoiding risking the user’s health. There are several areas and aspect to considering when improving for ergonomics. Mostly the physical aspects are considered, but areas such as information ergonomics and sight ergonomics are important as well (Bohgard et al, 2015).

When a handheld tool is designed several aspects need to be taken in consideration. Examples of these can be if the workstation requires standing or sitting, the work task includes vibration,
loud noises and forces and that different operator will have different body measures and abilities. If the wrong tool is chosen or designed poorly it can result in that one operator may lack capacity to complete the task or that the working posture becomes awkward (Lindqvist, B and Skogsberg, L, 2007).

Hands, shoulders and upper arms should be given extra attention when designing a work station. This since alignment between hand and forearm is important when force is applied. Extreme hand postures usually result in compensating with elevating the shoulder or raising an arm (Lindqvist, B and Skogsberg, L, 2007).

A way to avoid this is by designing with help of ergonomic methods and evaluations. Another aspect is to also use anthropometric measurements which means using collected data based on body measurements of a representative choice of people from the population. These are divided up into female and male and the 5%, 50% and 95% percentile representing the mean value and standard deviation of the populations’ measurements. The different percentile is used depending on what is designed and the space or distance it is used in (Hägg et al, 2015).

**Anthropometry for the ironing task**

According to Hägg et al. in the chapter of Physical Loads in Work and Technique on human terms the head and body should not be leaning forward when completing a task, the upper part of the arm should be as close as possible to the body and avoid twisted and asymmetrical positions. The body position is decided depending on the height above ground the work is completed. Hägg et al. also claims that it is of importance to distinguish the difference between work height and height of the work surface. The work height can be allowed to be much higher than the height of the work surface when tools are used. The work height varies depending on the type of work. Since ironing can be considered as light manual work, hand press downwards, forward and backward to move iron back and forth, the recommendation is a work height of 50-100 mm under elbow height (Hägg et al, 2015). This means that the height of the work surface should be adjusted depending on each user's elbow height and the height of the iron's handle.

Anthropometric measurements of the 95% percentile of elbow height, arm to wrist length and left and right hand width can be found in the table 1 below.

*Table 1 Anthropometric measurements from Hanson et al., Applied Ergonomics, 2008*

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow height</td>
<td>1181 mm</td>
<td>1130 mm</td>
</tr>
<tr>
<td>Arm to wrist length</td>
<td>317 mm</td>
<td>284 mm</td>
</tr>
<tr>
<td>Hand width, right</td>
<td>98 mm</td>
<td>86 mm</td>
</tr>
<tr>
<td>Hand width, left</td>
<td>96 mm</td>
<td>87 mm</td>
</tr>
</tbody>
</table>

In the article Applied Ergonomics by Garmer et al. about hand ergonomics they claim that when a power grip is needed the hand is the strongest when the posture is as close to rest position as possible.
Ergonomics for the hand

Lindqvist and Skogsberg claims in their book Power Tool Ergonomics that with tools the handle is usually compromised in favour for other functions. To give the hand the space it needs and to avoid uncomfortable pressures on sensitive areas as fingers and centre of palm the handle should be larger in order to distribute the pressure evenly on the hand. A recommendation is to let the handle be around 90 to 130 mm long so the muscles on each side of the palm can give support (Lindqvist, B and Skogsberg, L, 2007). According to Table 1 above, the 95 percentile anthropometric hand width for right hands are 98 mm for men and 86 mm for women when not pressed against a surface or applying force.

The shape and size of the handle often determines what force and precision the user can apply. Power grip is when the hand is wrapped around the handle while precision grip activates the thumb and one to two fingers like the grip when holding a pencil (Lindqvist, B and Skogsberg, L, 2007). Power grip is preferred when a large muscular force is required. The ability to apply precision is considered to decrease when the ability to apply force increase according to Hägg (2001, 8).

Handles that are held in power grip can increase precision by moving the thumb which helps guiding the force and increase the control of the object according to general conclusions by Napier (1956, 908).

The handle diameter is recommended to be in the range from 30 to 45 mm for power grip and for precision operations from 8 to 16 mm, since the handle diameter influences the ability to apply force. For larger diameters the force come mostly from the fingertips. It is harder for smaller dimensions since the fingers lose their capability to produce tension (Lindqvist, B and Skogsberg, L, 2007).

When developing products that are used by hand it is of importance to avoid deviation between the wrist and hand in order for the hand to be in a neutral position (Hägg, G 2001). A neutral wrist is acquired when the angle between the direction of the handle and the direction of work is between 70° and 80° (Hägg, G et al. 2015).

Deviation plane is where the hand is rotated towards its little finger or the thumb in a one directional plane, see figure 4.

The motion of moving towards the little finger is called ulnar deviation and extreme angles in ulnar deviation cause severe wrist complications (Hägg, G 2001). Ulnar deviation is mainly dependent on the design of the product and the context it is used in and Hägg, G (2001, 40) writes about products that has been improved to reduce the extreme wrist angle within
products as knifes and hammers. Hägg, G (2001, 41) also mentions the fact that many of these concepts has not been applied in practise and the author assumes that this was since the precision in the wrist is high when positioned in ulnar deviation.

2.1.3 Function and design history

The first irons were developed during the late middle ages. They consisted of a handle and an iron body and used heat and weight to receive the desired results. A lot has happened since the first developed iron and this section will describe the functional and design history of irons.

**Functional history**

These first products were passive devices meaning they did not have a heating element and were heated on the stove (Kennon W.R., 2008). Heating the iron on the stove or fire meant that fabric stains were easy to get and the irons needed to be notorious cleaned with sand-paper and kept away from burning fuel (The Santee Historical Society, 2017). The first electrical iron was developed in the late 1800 (Bellis Mary, 2017). The electric irons were fitted with thermostats which for the first time enabled the heat to be regulated and not damaging the fabric.

Steam irons were introduced 1934. Steam irons uses moisture as a helping element when ironing which makes ironing faster and more efficient (Allt om Vetenskap, 2004), see figure 5 of an early steam iron from Wavery Tool Company of Sandusky.

![Figure 5. Steam-o-matic-iron from the 1940s (Sewing machine company, 2018).](image)

Improvements made since the development of steam irons have not been as remarkable but on another hand important for the safety when ironing as auto-off settings, removal of lime scale, scratch resistant soleplate and adding a combination of water spray and steam.

**Design history**

The functional development did not experience any remarkable changes since the steam application in 1930's but more has happened to how it has been designed. A timeline of the design development was created and presented in figure 6. A larger version of the time line
can be found in Appendix B. The time line visualised that the handle of the iron had the focus in the early development of iron. The handle was assigned a unique material to make it stand out from the body and curved surfaces to enhance comfort. Around 1980s the design then transformed into straighter lines and more square shaped irons in plastic. In 2000 the stream lined irons entered. These irons have a more forward pronating handles incorporated in the body and curves to enhance the speed of ironing. Irons still look like this today but since the last couple of years irons challenging the shape of handles, soleplate and other function can be found, see figure 6.

![Figure 6. Design development of irons from 1950’s to present time.](image)

The design development from present time might take the same direction as Electrolux did when developing their vacuum cleaner, ErgoRapido in figure 7. ErgoRapido was developed with the intention of having a design that would be desired to have on display for fast and easy access (Electrolux, 2018 (2)).

![Figure 7. Electrolux vacuum cleaner ErgoRapido that was designed to be on display (Electrolux, 2018 (3))](image)

Kitchen appliances have also undergone a design development as the status of the kitchen has risen from being a room for servants into a room for social gatherings where the interior plays
2.2 State of the art

A State of the art investigation was conducted with the intention of identifying products available within ironing, market evaluation of the brands in this area and presentation of products that have a similar area of use.

There are several brands which deliver crease removal solutions today. Within the industry sector several larger solutions exist where the clothes are ironed on more high technology iron boards with build in vacuum functions with the combination of steam irons (Leifheit, 2018). Some solutions even invite the user to put several clothes on hangers on a line and then the machine steams the clothes inside the machine and ends with folding or putting plastic around them at the end (Fergusson, S. 2015).

There are newer solutions recently coming up onto the market which steam the clothes in smaller closet like solutions for private users too and hand-held steamers are becoming more and more popular. LG has also released a steam closet which steams the cloth inside a closet while you can do other things (LG, 2018). The product is very expensive, but moving towards letting the machine do the job like in industries.

Smarter iron boards with vacuum abilities exist for private user too but are not as common as the regular ironing board which works more as a foldable table. The most popular tool is the steam iron though. Steam stations exist as well but is newer on the Swedish market and takes up more space to stove away.

The leading brands on the market is Philips, Tefal, Bosch and Electrolux. There are several more brands as Rowenta, Solac, Bauer, OBH Nordica, Morphy Richards etcetera. All the brands offer similar solutions, which is dry-irons, steam irons, travel irons and the larger brand often have the steam stations and steamers as well. To diversify their products, compete about better effects, pressure of steam, faster heating, safety mechanism and lime scale removal. Philips has created a solution called OptiTemp which is claimed to be a sensor which senses the fabric and offers the best temperature for that fabric but is, after some research,
realised that they simply use one temperature for all fabrics, meaning that you will have to work longer and harder with fabrics which need a higher temperature and you end up using more steam (Which? Team, 2012).

Steam is in general the most used tool for removing creases. The steam favourable since it includes both heat and moisture, which is most successful when removing creases based on today’s research, but the iron itself also includes the ability to press or stretch the fabric in to new shape. A market evaluation was created in order to orientate the brands in comparison of each other, see figure 9. The orientation is based on the thesis authors’ view/estimation of the market after the conducted market research. The axis shows how the perception of the brands products in terms of pricing (x-axis) and innovation (y-axis) based on Alex Milton and Paul Rodgers method Perceptual Mapping from the book Research Methods for Product Design.

![Figure 9. Market evaluation](image)

2.2.1 Other interesting products

It is important to not only find inspiration from ironing products but also look to other industries to find solutions to similar functions. An area of interest were the electric planers, see figure 10.

![Figure 10. Electric planar with ergonomic handle. (Bosch, 2018)](image)
This product was used by both pressing down the product on to the material and pushing it forward. It was therefore interesting to see how the planar was designed in terms of the handles in order to draw conclusions of the most ergonomic angle for the handle when it comes to products that are used in a similar way as irons.

2.3 Patent search

A patent search was completed in order to find solutions that could inspire for new areas to develop within and to know what has been patented. Escpacenet (Espacenet, 2017) was used as search tool.

Several patents were found and used as source of information for section 2.1 Articles of scientific height. Below are the patents of most interest presented with a summary of its content. Figures of each patent can be found in Appendix C.

Some sections have been removed due to confidentiality.

The tilting handle

Patent Iron with tilting handle GB2438619 highlights the problem of strained wrist when ironing and presents their solution to the issue. The patent visualise an iron with a handle that can tilt to the sides with an angle of 4 to 10 degrees relative to soleplate. The purpose of the handle is to reduce strain in wrist when manoeuvring the iron (UK patent No. 2438619, 2007).

Fan for drying fabric from moisture

Patent Iron equipped with drying means EP1837435 is equipped with a fan that is described to cool the fabric after ironing. The fan would operate transversally to the ironing direction and be positioned inside the soleplate. The purpose of the fan is to reduce time when ironing (EP Patent No. 1837435, 2007).

Detachable soleplate

Patent Steam iron CN107087419 describes a solution with a detachable soleplate. The existing soleplates are glued together which prevents access to its internal parts as the steam chamber. This patent enables access to its internal parts, by removing attachment which facilitates cleaning of the iron, with the purpose of removing lime scale clogged in the steam vents (CN Patent No. 107087419, 2017).
3. Methodology

This chapter includes the methodology of how the following areas were managed: Investigation of current solutions, user study, identification of areas of improvements, idea generation and design brief. The result of each area will be presented continuously.

3.1 Investigation of current solutions

An investigation of the existing ironing methods was conducted in order to learn how the various features perform and gain insights and data to compare with for the upcoming product development. The following areas were investigated: crease reduction ability, energy consumption, moisture used and left in fabric, temperature on fabric after ironing and cooling time and how vacuum cleaner and hair drier affects the pressing and cooling result.

3.1.1 Crease reduction test

The first test had the purpose of determine which product and function was best at removing creases. The following products were used: garment steamer (Rowenta), steam iron light weight (5Safety), steam iron heavy weight (5Safety) and steam station (AEG), see figure 11.

![Figure 11. Products used in crease reduction test from left to right: Garment steamer (Rowenta), Steam iron light (4Safety), Steam iron heavy (5Safety) and Steam station (AEG).](image)

A flat iron was also added as its capabilities of working as an iron was of interests. This test was inspired by the IEC 60311 standard which was used when professionals determine the performance of their ironing products. This standard was used in order to receive a result that was repeatable, comparable, and therefore trustworthy. The IEC 60311 standard will unfortunately not be further explained since it was not available for further distribution.

Method

Cloths were creased inspired by the standard to have the same conditions for every product. Both cotton and jeans fabric were used. The cloths were then ironed according to the standards. The ironed cloths were then graded and compared with the rest of the ironed cloths. Each test was conducted twice with different users and the grading was done individually to avoid influencing each other.

Result

This section has been removed due to confidentiality.
Conclusion
The test showed that flat iron was the best product at removing creases but not realisable as it was limited in its abilities to access the middle part of fabrics.

This section has been removed due to confidentiality.

3.1.2 Energy consumption
The investigation continued with measuring how much energy existing product consumed.

Method
Consumed energy was measured for both starting the product and using it. Each product was used for six minutes. The result was then multiplied with ten to receive the energy consumed when ironing during one hour. The products with steam were set to full effect.

Result
This section has been removed due to confidentiality.

Conclusion
This section has been removed due to confidentiality.

3.1.3 Moisture consumed and left in fabric
A moisture test was conducted with the purpose of learning if there were any connections between the previous crease performance and used moisture.

Method
The test was divided into three parts, the first part investigated used moisture, the second moisture left in fabric after ironing and this section has been removed due to confidentiality.

Part one
The first test required a scale. The investigation started with measuring used moisture. Each product was weighted before each test and then used for one minute to be weighted again. The products with steam were set to full effect.

Part two
The test continued with measuring moisture left in the fabric after ironing. Each cloth was prepared by dry ironing it to remove room moisture. The room moisture in the lab was 23% which had to be ironed out to not affect the result. The start weight of the cloth was noted. The cloth was ironed using the same method as the energy test for one minute and then weighted again to learn how much water was left in the fabric. The cloth was also vacuumed and blow dried to see if that would decrease the remaining moisture after ironing inspired by findings in 2.1 Articles of scientific height and 2.3 Patent search.

Part three
This section has been removed due to confidentiality.
Result Part one

This section has been removed due to confidentiality.

Result Part two

There was not a noticeable amount moisture left after ironing with steam iron or using the spray of a dry iron: approximately 0,04 g. Vacuuming and blow drying after ironing only increase the weight of the fabric as it made the fabric absorb the room moisture.

Result Part three

This section has been removed due to confidentiality.

Conclusion

This section has been removed due to confidentiality.

Using a vacuum or blow drier increase the moisture in the fabric but not more than its start weight.

3.1.4 Temperature

Heat is one of the key factors needed for ironing. It relaxes the fibres and enables them to be straightened out. It is therefore important that the heat decreases fast after ironing or new creases would be created. A temperature test was therefore conducted with the purpose of learning which product enabled the fabric to cool down the fastest and if there could be anything added to accelerate the cooling. Since the literature study had showed that vacuuming was used to fixate the fibres in the industry, the test was complemented by vacuuming and blow drying the fabric to learn if it could affect the result.

Method

A cloth was ironed for one minute and then an IR thermometer measured the starting temperature and how the temperature reduced over time. Some cloths were also vacuumed and blow dried for five seconds after being ironed to see if that could decrease the temperature faster.

Result

- Ironing using either method increase temp from room temperature 24,7°C to approximately 90 °C.
- Took 90 seconds to cool to 36 °C in room temperature when laying on the board. Took 5 seconds to cool temp to 36 °C with vacuuming or blow drying when laying on the board.
- However, it took only five seconds to cool down the fabric to 36 °C when lifting up the cloth and waving it in the air.

Conclusion

The cloth should be removed from the board after ironing to enable it to cool down as fast as possible. The board was assumed to affect the cloth negatively by passing through heat and moisture. It was not worth the work of using a vacuum or hair drier to cool down the fabric as it had the same effect as lifting the fabric of the board.
3.1.5 Summary test conducted

The products that were best at removing creases were:

*This section has been removed due to confidentiality.*

The products that consumed the least amount of energy were:

*This section has been removed due to confidentiality.*

The products that consumed the most amount of energy were:

*This section has been removed due to confidentiality.*

The temperature decrease fastest by lifting the fabric from the board, vacuuming it or blow drying gave the same result but requires a bigger effort.

3.2 User Study

*This section describes the user study of the process starting with the study including survey, observation, and deeper interviews and then a concluding part where personas, customer journey, list of opportunity and problem areas were created and finishing off with a function analysis.*

A user study was conducted to get an understanding of users underlying needs, issues with the product and their habits and experience of ironing. The target group was, to start with, both men and women within twenty to eighty-five to avoid assumptions of who irons, but within Sweden to simplify getting in touch with individual users. After the study was conducted the target group was narrowed down and three personas was created to represent the new target group.

The study started off with a survey for quantitative data, then an observation including follow up questions and deeper interviews with users from the survey for qualitative data. In every study at least five participants within the target group were wanted. This since studies and an equation by Jakob Nielsen and Tom Landauer show that the number of usability problems discovered does not increase the greater number of users you include (Nielsen, 2000), (Virzi, 1992). So, the more users included the less you learn from each participant and valuable time of the project is wasted. By the fifth user Nielsen and Landauer claim with the equation that more than 75% of the problems have been identified and by the fifteenth you have discovered 100%, see figure 12. Instead the recommendation is that the time would be better spent doing several smaller studies with follow up studies than one larger study.
3.2.1 Survey

The study started with a survey to get a broad understanding of who irons, what irons they use and what they are looking for in an iron. Here the goal was to receive as many replies as possible and a survey was therefore a good alternative to get quantitative information. Open answers were limited by only using the option "other" when the answer they wanted was missing and they could fill in an alternative reply. This saved time when evaluating the collected data, but still opened up for the opportunity to gain insight of options that was unknown.

The survey was conducted online and distributed to two network community groups on facebook.com about cleaning tips. A total of ten multiple-choice questions were formulated with use of the book Research Methods for Product Design (Milton et al. 2013). The full survey and summary of the replies can be found in Appendix E.

A total of 404 participants completed the survey with 383 women while the ages varied evenly between the ages 21 to 61+, see figure 13.

Most participants used steam when ironing and 24% also used a separate water spray, see figure 14. Mostly shirts, blouses, table cloths and curtains were ironed and only 20% irons every week, see figure 14. A shirt was estimated to be ironed within 5 minutes and most participant looked at effect, price and steam capacity when they bought their iron or had received their iron as a gift.

Figure 12. Curve of problem identification (Nielsen, 2000)

Figure 13. From left to right: Gender distribution of participants, Age distribution of participants
There were mixed feelings between having automatic steam function or deciding themselves when to apply steam, but getting to decide temperature, having a water spray and being light was of importance. When asked what they wished their iron could have or be more of, 31% answered that they wished it was more ergonomic, left the clothes dryer or made the clothes smell nice and 40% also wished it took less time. In several of the questions the participants under the option "other" answered that the cord was a problem and wished the iron did not have one or was longer.

**Main findings:**

- Users from all ages between 21 to 61+ irons
- Users like to have control of moist application and temperature settings
- Ironings is considered time consuming, some find it relaxing
- Wishes the iron was more ergonomic, gave better result, had no or longer cord and left the clothes scented
- Many participants look for effect, price and steam capacity when buying an iron and almost 25% received their iron as a gift

### 3.2.2 Observation

The purpose of the observation was to investigate if there could be any improvements done to the performance of the functions of the iron and the way they are arranged on the device.

Aspects that were investigated:

- How does the user interacts with the device?
- What problems occur when ironing?
- What pain points were there?
- Are the functions arranged in the most optimal way?
- How does the user grip and handle the iron?
- Which kind of moisture was preferred and in what way it was used?
- How do they moisture when ironing, before, during, after and why?
- Why they iron like they do. Have they seen results of performing this way or learned from someone else?
**Method**

Five participants were decided to be invited for individual observations according to the recommendations by Nielsen's and Virzi's studies, (Nielsen, 2000), (Virzi, 1992). The participants were randomly picked from the office of Electrolux. This since the participants at this stage did not need any specific experience from ironing nor have used any specific brand or type of iron. They consisted of 3 women and 2 men, where 2 had experience of frequent ironing and 3 had little to no experience. The ages were spread between 21 to 34 years old and had different nationalities, but all lived in Sweden since a few years.

The observation was performed by two people, one moderator and one observer. The moderator instructed the person being observed of what to do and why the study was performed. The moderator used a script to make sure that every participant got the same information. The observer registered every action the person did and if the person needed guidance from the moderator. The study was filmed to make sure nothing was missed.

The observation was followed by questions regarding their experience from the ironing session, when and why they decided they were done, why they chosen the functions they did and how and whom who had taught them to iron. Each questions was followed by five why's, which is a technique used to understand underlying reasons to feelings and actions (Stickdorn et al, 2011).

A second less structured observation was performed with two participants to confirm if some of the gained insight was repeated and to see how they used the functions on another iron.

The full instructions, a summary of the two observation and interviews can be found in Appendix F.

**Main findings:**

- Users with little to no experience had a hard time understanding how to set the temperature since the light showed a green colour and they did not understand or see the round button for the temperature.
  - As a result two participants put their hand on the soleplate, but realised it was cold.
  - Extra guidance had to be given to where the button was located.
- The buttons showing steam options was confusing and some though they added the steam by pushing the extra steam button lightly, while the steam actually was set to automatic. The extra steam button also needed to be pushed harder in order to generate steam.
- All participants held the iron in a way which strained their wrist. Some leaned in an angle with their body to compensate for the angle, see figure 15.
- Several users did also iron sideways or in circles and held the handle and ironed as if it was horizontal.
- They had a hard time seeing the result, which made them stop and lift the fabric up several times.
- When using the spray on the iron several participants lifted the iron to get a better precision on where the water was sprayed, see figure 15.
• One participant used the separate spray and sprayed the whole cloth before ironing.
• The table was not adjusted for each participant’s height, neither did they ask to get to set the table to a different height. This should have been done to make it more ergonomic for each user.

Figure 15. From left to right: Angled body & wrist, Angled wrist, Lifting iron to use spray.

3.2.3 Deeper interview

A deeper interview was created to get a better understanding of users ironing habits. This gave the opportunity to ask open ended questions to fewer users and still get enough data to base inputs on. The interview consisted of 26 questions with follow up questions parted up into the sections background, ironing habits, storage, use and after use, see Appendix G.

The goal with the deeper interview was to get a better understanding of where in the home they iron, what they think about their iron, where they keep their iron and iron board and what their ironing procedure look like.

A total of ten users were interviewed, seven women and three men, whom all had participated in the survey and all ironed frequently. Ages were spread between 23 to 85 years old.

Main findings:

• The interviewees thought ironing was time consuming and they wished to have everything out, ready to be used. Since the iron and iron board's design are not part of the interior and looks like a cleaning device, they should therefore be stored in the cleaning cabinet. They could be on display in the laundry room, but these rooms are however often small, and the products are therefore stored in a cabinet, closet or behind something.
• Depending on the amount of fabrics that needed to be ironed and that several users claimed that the iron board is a hassle to put back and forth interviewees says that they mostly iron close to where it is kept when it is only 1-2 items. Otherwise they place it somewhere where they have more space, good lighting, furniture to lay ironed items on and can listen to music, radio or watch TV at the same time. These spaces tended to be in the kitchen, living room or laundry room.
• They let the iron to cool for 30 minutes to 2 hours in order to put it away as fast as possible. This was claimed as an annoying moment as they do not feel finished until it is stored away. It was perceived as it takes up too much room space and makes the room look untidy.

• The users' iron design was usually colourful and bright, with several plastic parts and a see-through tank for water. Several thought the iron looked cheap and that the cord was stiff, in the way when ironing, too hard to roll up, too hard to unplug or too short. They wished to have an agile and slim iron that looked like it easily could reach between buttons and collars.

• Several interviewees used extra water spray since the spray was not efficient enough on the iron and do not like the build-up of lime scale in the iron that comes from the steam.

• The buttons and functions was wished to be easy to understand and placed in a way so you do not accidentally touch them and change, for example, the temperature setting.

3.2.4 Personas & Customer Journey

To create more credibility to the project and to clarify who to develop for personas were created based on the gathered information from the survey, observation and interviews. These personas represented the possible customers for the new iron and it was of importance that their needs were fulfilled in order to create a successful product.

Persona 1: "Minimalistic Marcus"

• Male, 37 years old, in a relationship and works as an aerospace engineer, see figure 16. Spends his weekends at his local climbing centre or working on own mechatronic projects at home. He owns a two-room apartment together with his girlfriend and they thrive for minimalism to be able to keep a clean and tidy home. High quality in clothes, technology and furniture is of importance for Marcus since he rather invests in well thought through products than mass production. He likes to try out new technology and trends and his latest update is his wireless speaker system which he controls through an app and an energy consumed app which counts the amount of energy used by each product in his home. He likes the control which comes with this app and the simplicity of controlling all system through his phone. He mostly wears shirts and chinos to work, but when he dresses up he tends to wear a suit. He dry cleans his suits and finer coats but likes to iron his shirts and chinos by himself because it is cheaper and he does not have to go back and forth to the dry cleaner every week. Marcus does most of the ironing at home since his girlfriend mostly wears clothes which does not require ironing.

• Quote: "I iron my shirts with an iron that was reviewed as the best performing on the market and I like it because it has more advanced functions such as auto clean for lime scale and automatic off feature".
Persona 2: "Career focused Anna"

- Woman, 55 years old, married and mother of two, has a career within law and tend to work long hours during weekdays, see figure 17. On weekends Anna likes to take care of her home and spend time with her family. She likes to keep up a good appearance a clean and tidy home and has filled it with her many Danish design furniture she has collected throughout the years. Her favourite piece is her black Y-chairs from Hans J. Wegner. She thinks ironings is relaxing and that it is important to take care of her clothes and to be perceived as a clean and organized person. She irons blouses, trousers, sheets, kitchen towels and her husband's and sons' shirts. Since she has had her iron for a long time and she plans to update herself with a new and more contemporary iron. She has experienced some trouble with lime scale with her old one and want something that is easier to maintain.

- Quote: "I iron everything, but the constant lime scale and short cord is a hassle to deal with and my wrist feels tired afterwards".

Figure 17. Career focused Anna, (Rawpixel, 2018)
Persona 3: "Sustainable Madelene"

- Woman, 32 years old, married and mother of two, work as a high school teacher, but is currently at home on parental leave with her second child, see figure 18. She is very engaged in her community within environmental questions and thinks a lot about how the planet, her children and their future children will look like. She recycles her garbage, has a compost in her backyard and grows as much vegetables and fruit as her garden can handle. She enjoys buying things second hand since she believes that the clothes or furniture can look as new with some love and care, plus it is a great way to save money. She has a steam iron today and combines it with a separate spray for tougher creases. She irons everything from her nicer children's clothes, t-shirts, shirts and linens.

- Quote: "I use a separate water spray to straighten out tougher creases as the implemented spray on the iron does not give me the result I want, it gets too wet and I cannot control were it ends up".

![Figure 18. Sustainable Madelene, (Dummer, 2018).](image)

**Customer Journey**

A customer journey was narrated for the three personas. They were based upon conducted user research and contained events happening before, during and after ironing. The full customer journeys can be found in Appendix H. Each action was given an emotion to highlight when the user experienced a pain point or a positive feeling. This gave an overview of what could be improved to give a customer a better ironing experience. The three needs for each persona of the journey were:

Marcus' needs:

- Efficient and agile iron that maintain the tidiness in the room it is in.
- Maintain ironing flow, avoid abruptions as refilling water tank.
- Easier to put away iron when done. Fewer steps needed.

Anna's needs:

- The mobility of ironing, being able to iron close to the family.
• Efficient and ergonomic iron.
• An iron and board that goes well with the interior of the home.

Madelene's needs:
• Energy efficient iron with better water spray.
• More time efficient ironing method and its arduous to store the iron and board.
• Improve safety around ironing.

Common steps and problems:
• They all move their irons and irons boards to the living room to iron at the same time as doing something else, as for example watching TV.
• They experience problem when filling the water tanks since the hole is narrow. Have to refill the tank during the ironing process.
• They sort their clothes after the temperature needed for most efficient ironing. Lower temperatures first and then higher.
• Madelene uses a separate water spray since the spray on the iron is not spreading the water enough.
• Uses extra moist for tougher creases
• Lime scale is a problem during both the prep of ironing, during and when they are done ironing as it leads to extra maintenance and damaged clothes.
• They hang clothes to avoid recovery of creases, but do not have anywhere good to hang them close to where they are standing.
• Storing afterwards is not easy when iron is still warm. Takes too long to cool down. The irons and iron boards do not fit with the interior which annoys the user.
• Efficiency is of interest for all three users

Main findings:
• Design of the iron needs to be cohesive with the environment it is used in
• Refilling the tank and using the water spray on the iron is a problem
• The iron need to be agile, efficient and easy to use for a good experience
• An iron which uses less energy and is more environmental friendly is of interest
• Lime scale is a common problem and an area of opportunity to improve
• The iron would benefit of an ergonomic and usability evaluation

3.2.5 Opportunity and Problem Areas
Several areas for further investigation were found from the tests and user study. To decide which areas to focus on and which were more urgent to solve, the areas were ranked from one to four. Since the project was divided into primary and secondary research the areas ranked with one belonged to primary research and the areas ranked with two to secondary research. These two priority categories were decided to be used to create the list of requirements and the areas with ranking three or four would be areas which would improve the result of the project, but only be solved if time was available.
1. This section has been removed due to confidentiality.

2. Position of functions
   Handle / Ergonomics
   Designed for context where used
   Buttons
   Lights
   Intuitive design
   Semiotic information

3. Sliding capacity
   Effect
   Moist left in fabric
   Weight of iron
   Lime scale
   Feelings: Time consuming / boring

4. Crease recovery
   Cord length or cordless
   Soleplate shape

3.2.6 Function analysis
A function analysis was created to divide the product into functions before thinking about the solutions. This opens up for understanding and identifying the actual problem before trying to solve the task and to new solutions that solves the same problem but in a different way than what you traditionally expect (Landqvist, 2001, p.34). By identifying the products functions new areas and opportunities can also be found. A function analysis is also a way to understand why the function is there in the first place.

The function analysis in this project was divided into three areas, the basic functions of removing creases, the functions of removing creases with an iron and the irons body's functions, see table 4, 5 and 6.
### Table 4. Basic functions of removing creases

<table>
<thead>
<tr>
<th>Function</th>
<th>Class*</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce</td>
<td>MF</td>
<td>on fabric</td>
</tr>
<tr>
<td>Maintain</td>
<td>N</td>
<td>of fabric</td>
</tr>
<tr>
<td>Enable</td>
<td>N</td>
<td>of fabric</td>
</tr>
<tr>
<td>Avoid</td>
<td>N</td>
<td>on fabric</td>
</tr>
<tr>
<td>Offer</td>
<td>N</td>
<td>on fabric</td>
</tr>
<tr>
<td>Enable</td>
<td>N</td>
<td>finish of fabric</td>
</tr>
<tr>
<td>Enable</td>
<td>D</td>
<td>of fabric</td>
</tr>
</tbody>
</table>

### Table 5. The functions of removing creases with an iron

<table>
<thead>
<tr>
<th>Function</th>
<th>Class*</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Express</td>
<td>D</td>
<td>to user</td>
</tr>
<tr>
<td>Own</td>
<td>N</td>
<td>to user</td>
</tr>
<tr>
<td>Explicate</td>
<td>D</td>
<td>of product</td>
</tr>
<tr>
<td>Offer</td>
<td>N</td>
<td>on fabric</td>
</tr>
<tr>
<td>Offer</td>
<td>D</td>
<td>on fabric</td>
</tr>
<tr>
<td>Spread</td>
<td>D</td>
<td>on fabric</td>
</tr>
<tr>
<td>Distribute</td>
<td>N</td>
<td>in sole</td>
</tr>
<tr>
<td>Claim</td>
<td>D</td>
<td>to user</td>
</tr>
<tr>
<td>Offer</td>
<td>D</td>
<td>for all functions</td>
</tr>
<tr>
<td>Vary</td>
<td>N</td>
<td>in product</td>
</tr>
</tbody>
</table>

### Table 6. The iron’s body’s functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Class*</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own</td>
<td>N</td>
<td>to user</td>
</tr>
<tr>
<td>Tolerate</td>
<td>N</td>
<td>on sole</td>
</tr>
<tr>
<td>Enable</td>
<td>N</td>
<td>on product</td>
</tr>
<tr>
<td>Enable</td>
<td>N</td>
<td>of product</td>
</tr>
<tr>
<td>Enable</td>
<td>N</td>
<td>the product</td>
</tr>
<tr>
<td>Tolerate</td>
<td>N</td>
<td>while handling</td>
</tr>
<tr>
<td>Facilitate</td>
<td>D</td>
<td>on fabric</td>
</tr>
<tr>
<td>Enable</td>
<td>D</td>
<td>for all genders</td>
</tr>
<tr>
<td>Fit</td>
<td>D</td>
<td>with either hand</td>
</tr>
<tr>
<td>Offer</td>
<td>D</td>
<td>to user</td>
</tr>
<tr>
<td>Avoid</td>
<td>D</td>
<td>to user’s wrist</td>
</tr>
</tbody>
</table>
3.3 Idea Generation

This section describes the idea generation of the process starting with list of requirements and then the process of coming up and evaluating ideas in preparation for prototyping. The section finishes off with a design brief consisting of a verbal and a visual brief for the new iron.

3.3.1 List of requirements

The requirements were created with help of functional analysis and the list of opportunity and problem areas, see table 7 and 8. Since several requirements were not measurable with data the reference product Electrolux steam iron 5safety were used to compare with.

Table 7, Functional requirements

<table>
<thead>
<tr>
<th>Functional requirements</th>
<th>Class*</th>
</tr>
</thead>
<tbody>
<tr>
<td>* N = Necessary D = Desired</td>
<td></td>
</tr>
<tr>
<td>Reduce creases on a mixture of fabrics with the same outcome as a steam iron or better</td>
<td>N</td>
</tr>
<tr>
<td>Maintain quality by avoiding damaging the fabric</td>
<td>D</td>
</tr>
<tr>
<td>Offer smoothness on finished fabric</td>
<td>D</td>
</tr>
<tr>
<td>Facilitate a surface to press the fabric</td>
<td>D</td>
</tr>
<tr>
<td>Offer and store moisture</td>
<td>N</td>
</tr>
<tr>
<td>Spread moisture evenly on fabric</td>
<td>D</td>
</tr>
<tr>
<td>Use water to moist the fabric</td>
<td>N</td>
</tr>
<tr>
<td>Reduce moist left in fabric after usage</td>
<td>N</td>
</tr>
<tr>
<td>Express function to user in a way which makes it easy and safe to operate</td>
<td>N</td>
</tr>
<tr>
<td>Offer usage without adding strain to user while handling</td>
<td>D</td>
</tr>
<tr>
<td>The product should enable user to know brand identity</td>
<td>D</td>
</tr>
<tr>
<td>Enable storage after use</td>
<td>N</td>
</tr>
<tr>
<td>Tolerate load from user while handling</td>
<td>N</td>
</tr>
<tr>
<td>This section has been removed due to confidentiality.</td>
<td></td>
</tr>
<tr>
<td>Reduce lime scale problem</td>
<td>D</td>
</tr>
<tr>
<td>Offer the ability to lift and stand the iron up while handling</td>
<td>N</td>
</tr>
<tr>
<td>Design should challenge todays designs of irons and express innovation</td>
<td>D</td>
</tr>
</tbody>
</table>

Table 8, Limiting requirements

<table>
<thead>
<tr>
<th>Limiting requirements</th>
<th>Class*</th>
</tr>
</thead>
<tbody>
<tr>
<td>* N = Necessary D = Desired</td>
<td></td>
</tr>
<tr>
<td>Offer a variety of temperatures from 0-200 °Celsius</td>
<td>N</td>
</tr>
<tr>
<td>Maximum one cord</td>
<td>N</td>
</tr>
<tr>
<td>The iron body should not exceed 300x170x150 mm</td>
<td>N</td>
</tr>
<tr>
<td>All components and electronics should fit within the iron body</td>
<td>N</td>
</tr>
<tr>
<td>Total weight of product should be lighter than reference product</td>
<td>D</td>
</tr>
<tr>
<td>Enable usage with either right or left hand</td>
<td>N</td>
</tr>
<tr>
<td>Handle design should fit both female and male hands</td>
<td>D</td>
</tr>
</tbody>
</table>
3.3.2 HMW – How Might We...

A method for narrowing down the problems to solve, making them into tangible solutions and how to solve them, the question "How might we solve..." can be put in front of the problem (Design Kit, 2014). This opens for discussion and makes it easier to understand what action is needed to solve the problem.

The problem areas of focus in the project were listed under category 1 and 2 under section "Opportunity & Problem Areas".

The completed exercise resulted in that four of the problem areas would benefit to be brainstormed around:

- Handles
- Buttons
- This section has been removed due to confidentiality.
- This section has been removed due to confidentiality.

The design for context was decided to be solved as a separate research since the design would depend on research of trends and interior and at the same time be dependent on the result from the above investigations. The intuitive design, semiotic information and lights would also depend on the ideas gained from above results and was decided to not be part of main focus but be kept in mind throughout the design process.

3.3.3 Brainstorming

The brainstorming was conducted together with five colleagues from the Advanced Development department at Electrolux. The invited colleagues all had experience of developing irons or small appliances for home care. This to gain valuable knowledge from their experience that could be useful in an early stage of the project.

The brainstorming method chosen for this exercise was the morphological matrix and trigger material in form of simple sketches, see appendix I, and pictures in a presentation. This morphological matrix method is based on finding several solutions to one problem area. Each solution was written on a post it to enable the ideas to be moved around. Four problem areas were chosen from the previous research that needed improvement and developed during the HMW exercise: handle, buttons position, this section has been removed due to confidentiality. The group was introduced to why these areas were chosen before each brainstorming along with inspiring pictures, see appendix I.

The areas were divided into two where the first part of the brainstorming focused on the handle and buttons and the second part on the this section has been removed due to confidentiality. The this section has been removed due to confidentiality was decided to be in the second part as it was more difficult to solve, and the group was therefore given more time to warm up with solutions around the handle and buttons before this topic. Each part was given ten minutes of sketching before sharing each person's favourite solution. The brainstorming session concluded with an A3 from each participant.

The bowling grip idea was welcomed by the most participants and the idea most explored further during the discussion. This section has been removed due to confidentiality. Handle was
suggested as horizontal, pistol grip, joystick, a round bun, bowling ball inspired holes, gel material and, as mentioned before, a glove. Buttons were to be placed around the front of the iron, clicking with pointing finger on handle, LED lights all around the iron for temperature indications and scrolling up temperature solutions. This section has been removed due to confidentiality.

A summary of the most interesting solutions for the project was afterwards combined into one A3 for each problem area, see appendix I.

3.3.4 Morphological matrix

A morphological matrix was created based on the summary of most interesting solutions from the brainstorming, see figure 19. This was used to get a good overall look of the ideas and to simplify work when evaluating them.

<table>
<thead>
<tr>
<th>Element</th>
<th>Visual Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle</td>
<td>Thre blade</td>
</tr>
<tr>
<td></td>
<td>Horizontal</td>
</tr>
<tr>
<td></td>
<td>Pistol grip</td>
</tr>
<tr>
<td></td>
<td>Bowling grip</td>
</tr>
<tr>
<td></td>
<td>Wrist rest</td>
</tr>
<tr>
<td></td>
<td>Thre rest</td>
</tr>
<tr>
<td></td>
<td>Ergonomic shaped</td>
</tr>
<tr>
<td>Buttons</td>
<td>Thermorator handle</td>
</tr>
<tr>
<td></td>
<td>The mouse</td>
</tr>
<tr>
<td></td>
<td>Handle cont</td>
</tr>
<tr>
<td></td>
<td>Lights around</td>
</tr>
<tr>
<td></td>
<td>Temp control</td>
</tr>
<tr>
<td></td>
<td>Lights &amp; function on joystick</td>
</tr>
<tr>
<td></td>
<td>Voice control</td>
</tr>
</tbody>
</table>

Figure 19. Morphological matrix of most interesting solutions.

Since all solutions did not feel realisable for this project elimination matrixes were decided to be created in order to evaluate the ideas equally.

3.3.5 Elimination matrix

The elimination matrix method Pugh's matrix was used to evaluate the ideas from brainstorming. The buttons and this section has been removed due to confidentiality were not evaluated as these features were depending on the this section has been removed due to confidentiality and shape of iron.

The criteria's were created with inspiration of the list of requirements and based on the possibility of creation for this project and relevance compared to today's market.

For the handle alternatives a regular handle was set as a reference and the alternative handles were evaluated with accordance to the reference, see figure 20.

Wrist rest was given a minus in the ability to put away the iron while ironing and it was therefore decided that this handle would be fitted with a tilting soleplate to facilitate this motion.

Joystick scored second worst which was mostly due to the moving part in the joint. The joint was therefore eliminated but the shape of the joystick was kept in the process as it had a potential to be an ergonomic handle.
Figure 20. Pugh’s Matrix handle alternatives.

In the second elimination matrix a reference was set as reference since this is the most commonly used alternative, see figure 21.

This section has been removed due to confidentiality.

Conclusion Pugh’s matrix

This section has been removed due to confidentiality.

All handle except from the bowling handle and having a joint in the attachment scored high enough to be considered as interesting enough to be developed as a prototype. The chosen handles had the potential to increase the ergonomics of today’s irons which was one of the set requirements of the final product.

3.3.6 Design Brief

To clarify project goals, its requirements and the products purpose and identity a design brief was created. The design brief was parted up into a verbal brief and a visual brief. These two complement each other with descriptions for deeper understanding and images for expressing feelings, colour palette, shapes and form.

Verbal brief

- Identify what the new product wants to be:
  
The product shall offer a way for the user to in a more ergonomic, comfortable, sustainable and efficient way reduce creases from fabrics than before.

- Describe the products main function:
Reduce creases on fabrics while maintaining the fabrics quality.

- **See the product the way the user see's it:**

  The user sees the product as a tool to make their appearance look more clean and respectful.

  The products shape makes it easier to reach narrow areas and reduce creases close to edges and seams.

  The products agility across the fabric makes the work more fun and less frustrating for the user.

  The shape of the product enables usage without adding strain to user.

  The product's weight helps press the fabric without adding more force than needed from the user's hand. The user applies only force to move the product forward and sideways by the weight of their hand and strength of their arm.

  The product has a clean appearance and radiates a feeling of quality and stability.

- **Describe the user and products personality:**

  The user uses the product as part of their cleaning routine and knows how the product is used in the most productive and efficient way to get the result they want.

  The usage can be anywhere in the home since the product is used for a varying time and in combination with other activities such as watching TV, listening to radio or with the company of others.

  Intuitive design and familiar functions are important for the user to make the usage as efficient as possible.

  The user knows that part of the product is warm and trust the brand to deliver a product which makes sure the product let the user know in a secure way when the product is ready to be used and that the pre-set temperatures are correct for each type of fabric.

- **Describe the attributes that decides the value of the experience:**

  The products shape, form and placement of functions makes the user experience the product as intuitive, easy to use and ergonomic for the wrist. The layout of the product is well thought out with chosen materials and colours that express quality and a design with a strong brand identity. The attributes strive to make the user proud of owning the product, wanting to identify themselves with it and therefore not feel the need to put away the product after usage.

- **Describe the product's reflection and contribute to the company's image:**

  The product gives the company a new and competitive role on the market with a more sustainable, ergonomic product, designed to better fit into users homes. The product will
help to motivate the need of always improving and innovate existing products and question if products have reached their full potential.

**Visual brief**

The visual brief was created in form of three mood boards as a complement to the verbal brief. Images and words describes the feeling, colours, shape and form for the design along with the brand Electrolux and in what context it will be used, see figure 22. Larger versions and image reference list can be found in Appendix J.

![Mood Board of Electrolux, Mood board in context, Mood board of design](image)

*Figure 22. From top left, right and bottom: Mood board of Electrolux, Mood board in context, Mood board of design.*

The four words chosen to describe Electrolux were sustainable, powerful, caring and reliable. This because of their history of delivering professional quality products which generate great results. One of Electrolux's core values is working for a more sustainable society and the user knows what they get when they buy a product from Electrolux. Images showing a powerful waterfall, strong pillars, a caring and nurturing mother and friendship along with plants integrated to a building and electronical products integrated to the home were chosen to visualise the words and what Electrolux is aiming for.
The mood board in context shows images of homes with interior style matching the users believed to use Electrolux's products and the rooms where the ironing is carried out. The style is described with the words Scandinavian, light, natural and warmth for a home with neutral colours, soft fabrics and well-designed furniture.

The last mood board visualises the design for the new product with desired shapes, forms, materials, colour combinations and design language that the product should follow in order to create an iron that express the quality Electrolux stand for. The iron is to be contemporary to fit the latest trends on the market, look and feel inviting and simple to use and surfaces smooth with a feeling of a matt finish. Many of the images shows products which can be found throughout the home, but most importantly in the rooms shown in the mood board in context. This illustrates that the process of ironing is not just conducted in a laundry room, but in other rooms in the home such as in the kitchen and living room area and the new product should be designed to fit in these rooms as well. Design guidelines are the smooth surfaces along with lines highlighting the change to a different material or shape. Colours are soft, transparent or gender neutral to make the product inviting for everyone and enable it to blend in with the interior and appliances in a home. Edges are welcomed to be mixed between rounded and sharp. The vases and containers are to also inspire for ways of containing water since irons has a tank of water and the leather details can be added for a more contemporary and inviting look. The headphones show a display with intuitive design which lights up when the product is turned on and with simple icons describing the functions.
4. Implementation and prototypes

This chapter explains the prototyping process for three different areas. First part explains the process of developing the technical solution, the second part the handle development and the third the development of design and shape of the iron.

4.1 Technical solution development

This section has been removed due to confidentiality.

4.2 Handle Development

This section describes the ergonomic prototyping process of the handle. This area was chosen due to the findings in the User study section. The prototypes were created in three iterations cycles with evaluations and improvements.

4.2.1 Handle iteration one

All ideas from the elimination matrix, see figure 20, except the bowling handle were created as fast mock-ups in the first iteration. It was important to test all varieties before eliminating them according to the elimination matrix since the physical interaction also plays a large role in the evaluation.

Guidance from ergonomic professor

Information and articles were gathered from Linda Rose, an ergonomic professor at KTH, regarding what factors to take in consideration when developing an ergonomic handle. The professor informed about the importance of creating a handle that guided the hand into a neutral position, similar to when holding a pencil.

Foam model

The handle prototypes were created in uniform polyurethane foam at KTH's lab using saws, file tools and sandpaper, see figure 33.

Figure 33. Material used when developing foam handles for iteration one.
Every handle was fitted onto a foam model with the dimensions of an iron to facilitate the testing. All prototypes were tested and evaluated, and the shape of each handle can be seen in figure 34 where the best performing handle was highlighted with a green square.

![Figure 34. A collage of foam models from iteration one seen from the side and in use. The green one picture was the handle that performed best.](image)

**Evaluation foam models**

The Pistol grip was the only handle that guided the hand into a neutral position. The other concepts strained the wrist by either flexing or forcing the hand to the side. The shape of the Joystick was not perfect as it forced the hand out of its neutral position, but it had potential and was therefore included in continued work. The Pistol grip and Joystick were the only ones that did not strain the wrist when positioning the iron in standing position, these two handles were therefore the only prototypes that were further developed. Comments regarding all handles can be seen below.

- **The 360 crutch handle** was comfortable for the hand because of the large surface to lean the wrist on and it was perceived to enable precision but strained fingers when lifting the iron.
- **The knob handle** was comfortable for the hand to hold and encouraged back and forth working direction but looked bulky and enabled low precision.
- **The horizontal handle** was not comfortable when it was positioned over the iron and made the user iron diagonally, see figure 35. This was assumed to happen since
the hand's natural rest position was when the handle was positioned diagonally to the hand, (Hägg, G, 2001). It was also hard to put the iron in standing position.

Figure 35. Horizontal handle ironing diagonal.

- **The wrist rest handle** was uncomfortable for the wrist and difficult to make it stand. The horizontal shape created the same problems as the other horizontal handle by creating diagonal ironing. The wrist rest solution also had a curved soleplate. This soleplate helped when making the iron stand, but not enough as it still strained the wrist that can be seen in figure 36.

Figure 36. Illustration of how a tilting soleplate would facilitate when placing the iron on its back.

- **The joystick handle** was experienced to twist the hand from a neutral position. The shape looked however professional and the engravings had the potential of adding comfort. The surface on top of the grip also had the opportunity to hold a display if desired. Adding engravings was therefore kept for continuous development.

- **The pistol grip handle** was more comfortable for the wrist than the reference product and made the user iron more naturally back and forth. Precision ironing was experienced to be better when the handle was tilted up to a 35° angle from the starting position of 40°, see figure 37. It was also easier to put the iron in standing position when the angle was changed.

Figure 37. Pistol grip with two settings. From left to right: 40- and 35°.
4.2.2 Handle iteration two

It was important that the handle would be designed with two aspects in mind: the shape should position the hand in a neutral angle and secondly make it easy for the user to place the iron in standing position.

**Sketches**

The iteration started with sketching possible concepts based on the previous Pistol grip and Joystick concepts, see figure 38, where the four concepts visualised to the right were perceived to perform best.

![Figure 38. An overview of the sketching process of the pistol grip handle.](image)

These four concepts were chosen for further development as they met the requirements and represented a variety in shapes that was important to avoid bias and presumptions before prototyping.

**Foam models**

Four handles were carved out of uniform polyurethane foam and pinned to an iron shaped foam. The angle of the handle was set to 35 degree, since previous iteration showed that this angle guided the wrist into a neutral position. These were then evaluated in relation to the reference iron, see Figure 39, where the best performing handles were highlighted with a green square.
Result of foam model

All handles positioned the wrist in a neutral position and felt comfortable when moving back and forth. The handles with more curvature towards the palm were perceived as more comfortable in relation to the straight ones. This was assumed to be since these handles gave a support for the thumb and shared the shape of a palm. It was noted that the curve would be harder to fit all sizes of hands and anthropological measurements would have to be investigated.

The "Two handles" and "Circle" performed best in the test of placing the iron on its back. This was since these handles offered the ability to change grip which enables the hand to move higher up the handle. The solution of multiple grip was not optimal as the hand had to be moved when placing the iron on its back but was considered better than straining the wrist when using the "Straight" and "Round" handle.
Calculation of angle

Conducted prototyping had resulted in an angle of 35° that was perceived as most comfortable. This angle had no empirical foundation and further investigation was therefore conducted to find the ultimate angle with help of anthropometric data and calculations.

No research was found regarding ergonomic angles for ironing and references had to be drawn to similar products that are ergonomically developed. One proven ergonomic development was the angle of a screwdriver called pistol grip. This angle is 70° between the palm and wrist according to Atlas Copco standards (Lindqvist, B and Skogsberg, L, 2007). The angle of a screwdriver was however not applicable to an iron as the direction of force was not the alike. The direction of force was horizontal when drilling and diagonal when ironing as the iron has to both move forward, backward and be pressed downwards into the fabric. It was also discussed whether the grip was going to be optimised for power or precision as ironing includes both.

Knowing that the work height for light manual work should be wrist in angle 100 mm below the elbow and the anthropometric data for length of forearm for both women and men calculations could be made to find the theoretical right angle for the handle, see section 2.1.2. The three sharp lines illustrates the upper arm, forearm and the axis of the handle put in a 70° angle, which is the angle when the hand is in rest position (Lindqvist, B and Skogsberg, L, 2007), see figure 40. The trigonometric calculation was used to find alfa which is the angle of the forearm. The length of underarm is called y and height of wrist from elbow x.

\[
sin \alpha = \frac{x}{y}
\]

Figure 40. From left to right, equation and angle for angle of arm

For women alfa was 20° since their under-arm length was 284 mm. For men the angle was 18° since their length was 317 mm. Since the angles were close to each other the angle 20° were chosen to go forward with. The next step was to find the angle beta in figure 41.

This would be the angle the handle would be to the working surface. By parting up the top angle of the triangle to a 90° corner and the rest, which in this case was 20° since 90° minus 70° equals 20°, the angle was 110°. If the right angle was 20°, top was 110° the left then had to be 50° in order to be a total of 180°, see figure 41.
The theoretical right angle of the handle should therefore be 50 degrees.

**Feedback from professor at Ergonomics Department, KTH**

Inputs and feedback was received from a professor in Ergonomics, Jörgen Eklund, with the intention of confirming if the received results from iteration two were accurate and ask for future guidance.

The professor highlighted the importance of having a grip that is versatile and enables the user to have more than one way of holding it as ironing is performed in several directions. The professor confirmed that the working direction for ironing is diagonally and that the calculations regarding a 20° angle between the upper- and forearm was a credible assumption. It was however difficult to determine how the grip could be adjusted in order to both enable a precision grip and a power grip. It was important that the handle was moved to the centre of the iron and as low as possible to reduce moment in the wrist and facilitate manoeuvring. Making engravings could enhance the precision grip.

However, the angle and the thickness of the handle was not a parameter that could be calculated using only literature. The professor claimed that it was of importance to start off with literature, but final outcome could only be decided through user tests since the ergonomics had not been researched enough previously.

**Inspiration from similar products**

Since the angle of the handle could not be decided solely on literature, investigations were performed to identify products with a similar operational direction and work height that had been developed with the user in mind. Inspiration was therefore gathered from electrical planers. Measurements showed that there were three different angles within these products; ~13°, 30° and 45°, see figure 42.
4.2.3 Handle iteration three

Conducted prototyping and calculations in iteration one and two resulted in two possible angles that could improve the ergonomics, 30° and 50°. Iteration number three consisted of quantitative and qualitative user studies. These user studies were performed based on the advice given from ergonomic professor in previous section with the intention to verify which angle and shape the users preferred.

Preparation user tests

Two irons were modified in order to have an angle of 30° and 50°, see figure 43.

The user study was divided into two parts. First part had a wide range of users to receive quantitative data and the second part was a lean test with few participants to verify the previous results and deepen the understanding in order to generate qualitative data. Both test included the two modified irons and one original. Every participant’s height, age and gender were noted and photos of how they interacted with the products were taken.
Quantitative user test

The quantitative test was performed by asking people who passed by in the hallway to try the three different irons and estimate which iron that felt best and answer why. Four foam handles from iteration two were also added to identify which shape and thickness of the handle that felt best, see figure 44 for the set up for the test. The thickness varied from 32 mm to 38 mm, some had a diagonal shape while others were circular.

Figure 44. The set up for quantitative ergonomic test with three irons and four shapes of handles that the user could choose from.

Result quantitative user test

It was an even spread in gender among the participants, 57 participants with 30 men and 27 women. The purple iron with an angle of 30° got most of the votes (49% of the votes), closely followed by the original iron (35% of the votes), Appendix K. The opinion regarding the angle of the handle did not differ between men and women but the shape of the foam models did.

Handle number 4 was the overall favourite with 54% of the votes. However, the second favourite differed among the genders. The men preferred handle number 2 and the women chose handle number 3. Handle 3 and 2 were close to each other with 28% and 23% and handle 1 got only 10%. Handle number 3 was therefore assumed to not be shaped for a man's hand and the same conditions regarding the handle number 2 for women.

Factors that could have affected the result was the height of the iron board as the participants could not adjust the height of the iron board. The results however indicate that the height of board was not an affecting parameter as participants of varied height most preferred the 30° handle and the original iron over the 50° handle.

Qualitative user test

The result gathered from the quantitative test had to be verified through a longer session since it was difficult for participants to make a decision after only holding the handle for a short
period. Their first impression might change after ironing for a while. Six participants were picked from the quantitative test who all were experienced in ironing and varied in height and gender. The qualitative test gave the participant more time to use the products and adjust the ironing board. The questions asked were more specific and had follow-up questions, see Appendix L.

The participants were asked to use all three irons. They ironed a shirt without heat since two of the irons could not be operated. The user was informed to iron for four minutes per iron and halfway through inform where and how much they felt in their body using a body map and Borgs CR10 scale (Rose, L et al, 2015). Same information was asked after the four minutes had passed and then every 30 seconds to identify when the sensations had ceased. Questions were also asked during the test to learn if the person could feel any difference between the three irons and why.

**Result qualitative user test**

The 30° handle and original iron were the participants' favourites and a summary of each iron is stated below:

- **Original iron:** Easiest to stand upwards make let it stand on its back.
- **30° handle:** Easiest to apply force on fabric though feels like it's going to tip when ironing sideways.
- **50° handle:** Too difficult to control when ironing details. Difficult to apply force downwards and to turn sideways. However, some liked it and felt that this iron was the easiest to move around and required less force than the other two.

The method of finding their physical impact could be improved for future tests using sensors or similar to gather more exact data and through that decrease human impact as it was difficult for the participants to identify the sensation when only ironing for four minutes. The conducted test therefore showed only the biggest sensations, see figure 45 for the result of the body map for all participants.

![Figure 45. Body map with a summary of the result for all participants. Highlighted area were the sensations where blue was low sensation, orange medium and red high.](image-url)
The above body map illustrated that the original iron and the 50° iron caused most negative sensations among the participants. This meant that the 30° handle performed best in the quantitative test and the quantitative test. It caused the least physical impact, improved force application and retained the user's precision. The 30° handle was therefore the chosen angle for the final product.

4.2.4 Conclusion Handle development

Above conducted prototyping and investigations resulted in a handle that needs to fulfil the following requirements:

- Guide the hand to a neutral position.
- Have the shape of a circle to fit both men and women.
- Have engravings for the thumb and index finger to enable precision grip.
- Enable the force from the hand to be transferred diagonally through the iron board.
- Have an angle of 30°.

4.3 Concept and Design Generation

*This section describes the design process of the iron. It starts with how concepts were generated with the help of sketches and then moves on to explain the model creation.*

The concept and design process started after the technical and a majority of the handle solutions were developed. This since the design was dependent on the measurements and requirements of the parts included in the solution. The exact angle and shape of the handle had not been set during the process of sketching but was implemented during model and Computer Aided Design, CAD, creation section.

4.3.1 Sketches

Sketches were created in four iterations and was inspired from the mood boards created during the idea generation, see Appendix J. A total of 40 concepts were generated during iteration one which then were narrowed down to the six most interesting shapes to further develop, see figure 46.
During iteration two each one of the six concept were explored further and around six new versions were generated for each concept, see figure 47.

For iteration three measurements were implemented to see if the concepts were realisable with the requirements and the components it would include. Electrolux 4Safety iron was used as reference for the measurements of soleplate and body's height and width. The mood boards were also used to make sure each concept included the chosen design features and shapes. Here the concepts number 2, 3, 4 and 5 were decided to be developed further, see figure 48.
Concept 1 and 6 were discarded because concept 1 was believed to overshadow the tip of the soleplate and concept 6 did not feel contemporary which was one of the words describing the new design in the mood board of design, see Appendix J.

<table>
<thead>
<tr>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Concept 2" /></td>
<td><img src="image2" alt="Concept 3" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept 4</th>
<th>Concept 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Concept 4" /></td>
<td><img src="image4" alt="Concept 5" /></td>
</tr>
</tbody>
</table>

Figure 48. Iteration 3, versions drawn with measurements and with considerations of components

After the third iteration the concept were compared and concept 4 and 5 were decided to be developed further into two final versions for the final design concept. These two would thereafter be investigated with more exact measurements and examination of how well all surfaces would connect to each other with help of models in cardboard or foam and CAD.

Iteration four therefore consisted of the creation of two final versions with colour to illustrate a more realistic appearance, see figure 49.

<table>
<thead>
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<th>Concept 4</th>
<th>Concept 5</th>
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<tbody>
<tr>
<td><img src="image5" alt="Concept 4" /></td>
<td><img src="image6" alt="Concept 5" /></td>
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</tbody>
</table>

Figure 49. Iteration 4, the two final versions of concept 4 and 5
Concept 4 had a removable water tank with a leather band. The green arrows illustrated its function and the inside components would be placed in a space positioned in the middle of the tank illustrated with a horizontal line of dashes in figure 49.

Concept 5 had a more compact design with the tank positioned at the front and the inside components in the back. This concept also had more space under the handle to make sure that any hand would fit when gripping the handle, see figure 49.

Both concepts had a similar shape of the soleplate and body with a large tank to see the amount of water inside and give associations of the vases found in the mood board, see Appendix J.

### 4.3.2 Models

Cardboard models were created in order to visualise the shape and size of the iron with a fast method. The soleplate and a side view was cut out and put together and compared with the 4Safe iron, see figure 50.

![Figure 50. Cardboard model next to Electrolux 4Safety iron](image)

The next step was to decide the exact shape of the tank and body. The idea was to have as round body as possible to follow guidelines from the mood board of design, see Appendix J. This complicated the fact that several components had to fit inside the body and the shape was therefore decided to be more rectangular, but with the option of having cut or rounded corners, see figure 51.

![Figure 51. Body shape options](image)

Both shapes fitted the mood boards design guidelines, and it was therefore decided to make simple CAD versions as well facilitate the evaluation, see figure 52.
Both shapes still felt appealing, but the design with round corners was finally chosen. This was based upon the fact that the tank’s shape shifts and becomes narrower at the front and the tank with round corners was best at expressing simplicity and smoothness by reducing impressions. It was also realised that the space in the middle of the tank for concept 4, see figure 52, was too small to have room for inside components. The tank of concept 4 would also be complicated to pull in and out when refilling the tank and it would be difficult to secure that the tank would not leak. The centre of gravity was also believed to end up too close to the front and therefore be unstable and unsafe when placed in upward position.

Making the tank wider was an option, but the measurements had to be a delimiting requirement since the iron should not exceed the reference 4Safety measurements too much. Concept 4 was therefore eliminated and concept 5 was further developed.

There were two areas regarding the design of the iron that still had not been decided during sketch iterations. One area was the front were the two sides of the iron comes together and meet and the second was the area where the handle comes together with the lower body. Another simple CAD model was created to explore these areas further with the combination of the tank, see figure 53.

The simple CAD model showed that the front had to be wider than first estimated and the handles connection to the lower body should be integrated better. It was also realised that the body looked long and heavy which could be changed by lifting up its back in an angle which would also simplify wrapping the cord around the body.

The simplest way to continue the design process was to create a version of the design in polyurethane foam. This gave the opportunity to fast and easy create the shapes of the front and back before building it in CAD, see figure 54.
The foam model gave several new insights. If the front was too wide it tended to look like a face. The front was therefore slimmed down as much as the water tank would allow and the top of the front was cut off to reduce the similarities of a forehead. Lines in the same angle was welcomed as much as possible to simplify the look of the design, see figure 55.

The final CAD model could be created when the final design of the foam model was established. The water tank’s and soleplate’s design was unchanged from the first CAD development, but the front and back had been changed and the circle shaped handle number 4 from handle development section 4.2.2 was implemented.

The CAD model was divided into a front part and a back part, a soleplate, water tank, a button and a cord holder with cord. The front and back part were created separately to divide the work and save time when creating them since both had difficult surfaces to produce. There were several complex surfaces to create which made the process complicated and more time consuming than expected. The CAD development was prioritized in the project as the result was considered important in order to present a realistic and more exact version of the vision of the design concept, see figure 56.
The final design was printed into a physical model using SLS (Materialise, 2018). The printed version had the purpose of illustrating the real size of the iron and its shape. The result of the printed iron can be viewed in figure 57.
5. Results

The developed iron has through literature studies, user research and technical investigations been improved within three areas: technical, ergonomic and design. Illustrations and specifications of data are stated in this chapter.

5.1 Summary of features

The developed iron has been improved within three areas that all combined has improved the iron's usability, sustainability and performance in comparison to today's irons. The solution could help Electrolux to differentiate among other brands by offering the only ergonomic iron with a unique design perspective. A summary of the technical, ergonomic and design solution is stated below.

Technical solution

This section has been removed due to confidentiality.

Ergonomic solution

The handle development has improved the ergonomics of the iron and created the following improvements:

- **Increase ergonomics**
  - The handle has been adjusted to a $30^\circ$ angle that guides the hand into a neutral position instead of having a pronating handle that could create ulnar deviation and strain to the wrist.

- **Increase usability**
  - Having a handle that does not strain the wrist and is design for both left and right hand enables more users to iron by making it available for everyone and thereby increase customer base.

- **Increase brand identity**
  - Offering an iron that promotes an ergonomic and sustainable lifestyle enhance the brand identity of Electrolux as a caring company.

- **Unique feature**
  - There are many irons out on the market that have similar features and it is sometimes difficult to stand on the shelf in the shops and conducted State of the art analysis in section 2.2 illustrated the tough competition. Having the only ergonomic iron enables a new selling point and could enable the Electrolux brand a chance to diversify from the other brands.
Design and Shape solution

The iron has been redesigned to fit better with its context and been given a more contemporary and clean design which had the following results:

- **Unique design**
  - The design of today's irons was very similar with a streamline design and included many curves. Having another design enables the product to stand out on the shelf which could increase the curiosity for this iron.

- **Reduce pain point**
  - The deep interviews and survey illustrated that users do not want to leave their iron on display since its design does not go well with their interior. This new design was designed for its context and thereby reduced the pain point when leaving the iron on display when it has to cool down as its design is not as diverse to the interior as it was before.

- **Increase usability**
  - The display and clean design reduced the previous scattered impressions and instead guides the user to where they should focus their attention and thereby increase the usability of the iron.

- **Enhance user experience**
  - Alternating the design to make it better blend with the interior of users' homes could enhance the experience of ironing and enable the users to associate more positive feelings to ironing which is today very disliked among many users according to conducted user studies.

5.2 Technical solution

This section has been removed due to confidentiality.

5.3 Ergonomic solution

The result of the ergonomic development was a handle with an angle of 30° towards the iron board. The quantitative study showed that 49 percent of the participants preferred this angle and the qualitative study illustrated that this angle had the least physical strain on the participants.

The shape of the iron was formed according to the circle handle that won the qualitative study. The 30° handle therefore got a rounded shape that followed the natural formation of a palm.

The handle was assigned with two grips, one for ironing and one to use when placing the iron on its back. Information from the ergonomic professor, Jörgen Eklund, highlighted the
importance of having multiple grips to offer versatile usage of the iron and reduce strains in
the wrist when alternating between ironing and pausing.

Figure 61 Top to bottom: Wrist angle when using new product, Comparing wrist angle between new
product and 4Safety iron.

The horizontal part of the handle was therefore created with the intention of being used when
placing the iron in an upward position as the 30° angle was not optimal for that task. The result
of the printed 3D version of the prototype in use is presented in figure 61. Appendix M
visualise the posture of the hand when going from horizontal to vertical position and back.

5.4 Design and Shape solution

The result of the design and shape concept is presented in this section. The presentation will start by
explaining where every function is positioned then illustrating how it is used and showing the new
features that have been added.

A concluding picture of the design concept with a suggestion of where the logo could be
positioned can be seen in figure 62.

Figure 62. The final design concept.
The final design consists of several details described in the list below guided by the numbers in figure 63.

1. There is a light under the iron along the soleplate to help guide the user when ironing by indicating in different colour that the iron is ready to use, green, or still heating up, orange.
2. An icon indicates that the water tank is filled from here. By pressing the surface, a spring opens the lid and the user can in an easy way fill the water tank and then close it simply by pressing the surface down again and feeling a click to confirm that the lid is closed.
3. Water tank has a wall thickness of 3 mm to give an encased and caring feeling of the water as the coffee machine on the mood board of design, see Appendix J.
4. The handle has a straight area to simplify grabbing the iron when putting it in upward position and down again.
5. A button is placed right by the index finger to simplify the control of applying moisture.
6. The handle has a rubber area to indicate that it is a handle and to give a more comfortable grip.
7. The handle has a circular shape in a 30 ° angle with a width of 35 mm for an ergonomic and comfortable grip according to the ergonomic study. It is also 125 mm long to fit larger hands.
8. The surface has a display which light up when plugged into the wall. The display is operated through touch and shows the user what setting the user has chosen and the temperature it has reached.
9. The cord holder works similar as a cord holders on hair products such as hair straighteners and curling irons. The technique is built on an axis which the holder is circled around. The cord will then hang downwards because of it striving for gravity and is therefore easy to move away from the handle if it is in the way. When the iron is put in upward position the cord will circle around and point downwards as in figure 63.
10. The cord is made of leather for a more inviting, contemporary, natural and interior look that connects to the interior of the mood board of in context, see Appendix J.

11. The rubber surface on the back of the iron gives the iron a more stable surface to stand on when placing it in an upward position and at the same time helps to hold the cord in place when it is wrapped around for storage, see figure 63.

12. The soleplate ends with an upward angle for simplifying ironing backwards and avoid crease recovery.

Figures below shows the iron from new perspectives to get a better understanding of the design and to show the iron from different angles, see figure 64, 65 and 66.

**Figure 64. From left to right front view and isometric back view**

**Figure 65. From left to right top view and bottom view**
The iron would come in two different colour versions, light grey with brown leather cord and dark grey with black leather cord, see figure 67. The soleplate, water tank, buttons, handle padding and cord holder are set as same to simplify manufacturing and be able to keep a lower stock. Both colours are natural, gender neutral, contemporary and fit into the homes on the mood board in context, see Appendix J.

The iron has a height of 169 mm, width of 120 mm and length of 295 mm. The handle has a diameter of 35 mm and is 125 mm long, see figure 68. The space between the handle and the iron body is 35 to 65 mm to give the user space for the hand and to avoid pushing a button on the display by mistake. The tank gives room for a total of 350 ml of water and the soleplate can flatten a surface of 226 cm².
The selected components for the prototype were weighted to estimate the final weight of the product. Weight of the parts:

- Inside components: 470 g
- Front and back part of product with approximately 4 mm thickness: 445 g
- Soleplate: 370 g
- Water tank: 140 g

The total weight of the product was estimated to be 1425 g without cord and 1570 g with which was heavier than the weight of a safety steam iron of 1350 g. The weight was assumed to decrease if producing the water tank in plastic instead of glass and the overall volume of the iron was presumed to decreased when producing as it was now over dimensioned with safety margins that could be reduce.

The water tank in the design concept can store 350 ml of water. This can be considered as too much, but the design would most likely change made more accurate for production and with construction constraints.

This section has been removed due to confidentiality.

The need of improving usability was one insights from conducted user study. Users who were new to ironing or did not iron frequently had trouble when turning on the iron and adjusting the settings. There were uncertainties whether the iron was on and how to adjust moisture alternatives. These two issues have been regarded during design development and a display and LED stipe has been added to the product. The display replace the knob that previously set the temperature. The display turns on when the irons connects to the outlet, which indicates for the user that a setting is required to start the iron, see figure 70. A LED stripe has been fitted around the soleplate that also illustrate when the iron is on. The LED stripe turns orange when plugged in to indicate that the iron is on but the right temperature has not been reached yet.

![Figure 70. Iron plugged in which lights up the display and a LED stripe around the sole.](image)
The display is operated through touch and the user can choose between the original settings of nylon, silk, wool, cotton, linen and max. A bar lights up to the chosen setting when the user has made its choice, see figure 71.

![Figure 71. Scenario when using the display of the iron that is operated through touch.](image)

A number in the centre of the display illustrates the temperature of the soleplate to both indicate that it is progressing into the chosen temperature, see figure 72.

![Figure 72. Illustrates how the iron visualise that the option silk has been chosen and the green LED stripe signals that it has reached the right temperature and is ready to use.](image)

The LED stripe turns green when the chosen temperature has been reached to indicate that it is ready to be used. Having a light around the soleplate also signals that it is in use and should not be touched to enhance safety for the user which connects back to performed observations where users were struggling to know when the iron was on. The iron was design to be better integrated with its context environment and reduce the associations to a cleaning devise that needs to be hidden in a cabinet. This allow the user to let it cool out safely in the open and therefore be easier to access for everyday use. The iron can be found standing on an iron board in a living room and on the table in a kitchen which is two of the rooms in a home it could be used and stored in, see figure 73 and 74.
The iron board was created to give an example of how the iron board could be redesigned as well.

**Inspiration from mood board**

The most used design guidelines for the process was light grey vase positioned on the left side in figure 75. The vase show how the product goes from one material to another and was used to design how the water tank could be integrated to the iron. Both the darker vase and the light grey vase had lines which indicates the shape of form which was also used when designing the iron. Their colours also inspired the colours chosen for the irons two colour versions. The black speaker had smooth surfaces and round corners which inspired for the
round corners on the water tank and iron body and the feeling of the surface on the iron body. The coffee machine inspired the thickness of walls for the water tank and the leather bounding on the chair motivated for the creation of the leather cord. The same function as the display on the headphones that lights up when turned on was used for the iron to help guide the user where the display is on. The chosen display enables the iron to maintain its smooth surface and simplicity which were in accordance with the chosen words in the mood board in figure 75.

Figure 75. Most used design guidelines from mood board
6. Discussion & Conclusion

This chapter start with discussion and then conclusion. Each section is divided into areas regarding different aspects of the project.

6.1 Discussion

The master thesis delivered a functional technical prototype, an ergonomic evaluation of irons today including a suggestion of improvement and a design concept designed to fit better in with its context of a home. The technical prototype was developed with the help of thorough testing and evaluation of current solutions. Guidance was given by Advanced Development Small Appliances at Electrolux regarding how they conduct their development, testing and possible investigations that could help the process forward.

Brand

In the market analysis presented in section 2.2 Electrolux was identified together with several other brand on the market of irons. This since no major differences could be found among the iron brands. By implementing any of the improved areas on the Electrolux iron would enable the brand to differentiate and move up against the radical axis on the market. The fact that no ergonomic iron nor an iron designed to fit into the interior of a home exist would give an advantage. This section has been removed due to confidentiality. The suggested solutions therefore improve the product, opens up for creating a better experience and would be a more sustainable solution. All three in line with Electrolux drivers.

Patent research

The project would have benefitted from a more thorough patent research. This since a patented solution of interest might have been missed because of the titles of patents did not indicate exactly what they were about and many times were in foreign languages. The patents were used as inspiration for possible solutions, learning what was already patented and as a source of information for the research that had been conducted when developing the patent solution. A patent search should also have been conducted after or throughout the process as well to secure the ideas were unique. Limited amount of time and skills of searching patents prevented this and the need of professional help would have been of importance in order to verify that the solution truly was unique.

User study

A new way of conducting user study was used, meaning completing several smaller user test with only five users instead of completing one larger test (Nielsen, 2000). This gave more valuable insights and feedback throughout the process and the time spent on conducting one larger test could instead be divided on several smaller tests. The experience gained from every conducted test also made next test more qualitative and effective since new perspectives and
insights of what to avoid was gathered. To have several smaller tests also opened up for the opportunity to conduct test before, during and after the development of prototypes.

The participants in the survey were mostly women. This was believed to be due to the type of community groups it was available for and that the members in the group were mostly women. The following user tests and interviews were therefore focused on having a more equal gender distribution, especially since assumption was gathered during the project that men iron equally or even more frequently than women. Discussions of ironing with participants in user test and people in general revealed that most men in their surroundings iron and sometimes even more than women since they iron their shirts while several women claim they avoid using clothes that needs ironing. If the survey would have been conducted again, other type of community groups and groups with more men would have been used.

The prototypes used for the ergonomic handle user test were of different designs which may have affected the participants’ opinions about them. The users were told not to mind the design and focus only on the handle and its angle. Most participants seemed to be able to overlook the design while others still commented the design. Some expressed they did not like changes and wanted the iron to stay as it was while others realised for the first time that the original handle was uncomfortable. The 30 ° handle was the favourite of the three on both the quantitative and the qualitative test and the result was therefore considered as accurate.

A third perspective was brought in for evaluation of the ergonomic prototype in order to verify that the calculation were correct and of scientific height. The ergonomic professor, Jörgen Eklund, from KTH confirmed that made assumptions seemed correct but recommended that ergonomic evaluations were always better and most accurate if user tests were involved. User test was completed with one quantitative and one qualitative test. The calculated angle of the handle was 50° but the most preferred angle according to user test was 30°. This confirmed Eklund’s recommendation that ergonomic evaluation was most accurate when user tests have been done as well.

**Time management**

Changes to the time plan had to be made along the process. New ways of conducting tests and additional tests came along which had consequence to the pre-set time as all three developed areas were conducted parallel to each other. The original time plan had three extra weeks for unexpected events and these were all used when the process moved over to phase B. An extra week was also added to phase B for rendering of pictures and finalizing the report.

The technical solution might have looked different if more time was available. The project had two promising areas to develop but one area had to be dropped due to too long delivery times and poor performance of available components. The technique did have several promising advantages though so if the project would continue the recommendation would be to evaluate the eliminated technique further.
Handling three areas

Findings from the observation and interviews during the user study made the project expand to include an ergonomic evaluation and the design process in addition to the technical solution. This also made the purpose and value of the project broaden to be about developing a new concept of ironing instead of only be about developing a technical solution. The new ironing concept was a result of developing with the users in mind and the fact that it expanded to three areas showed that ironing was in need of improvements, more than initially expected. Expanding the project to include three areas had an effect on the time plan and more investigations could have been conducted for the technical solution if there had been only one area to focus on.

Distributing the work

Each area of the project could of course have been more thoroughly developed if only one or even two areas had been part of the process. A majority of the time was spent on the technical solution while the ergonomic and design process were completed parallel to this. The reason why the project expanded was also because the project was completed by two people and not one meaning the double amount of time was available. To have two other areas were convenient when the process with the technical solution paused because of waiting time for parts to the prototype. Most work was completed together throughout the process and this was considered as most effective as both participants had to learn from the gained results and could therefore analyse the data from two perspectives.

The technical solution

This section has been removed due to confidentiality.

Design

The design concept was based on the mood board of design which in turn had been created based on the mood boards of the brand Electrolux and of the context it would be used. The context shows homes with interior visualising an interior style which may not represent all homes of Sweden but the homes of possible customers using Electrolux products. The goal with the design was to create an iron with a more clean and simple design which do not draw to much attention and disturb the interior style. It should blend in with the style and not be a statement product, therefore inviting to own and caring of the users' choice of style. The idea was also that the product now could get a spot in the home where it is not stored in a cabinet and hidden instead accessible for everyday use as intention of the ErgoRapido product of Electrolux see section 2.1.3.
6.2 Conclusion

A summary of the conclusions gathered from the development process are presented below starting with user study then technical, ergonomics and lastly design.

User study

The final product was the result of the information gathered from survey, deep interview, observations, technical tests and user tests. The master thesis was therefore based upon user needs, insights and feedback which resulted in a product that was improved with the user in mind. The purpose of creating a better user experience was therefore fulfilled.

Technical

This section has been removed due to confidentiality.

Ergonomic

The ergonomic suggestion was developed using user observation, research, prototypes, calculations and user tests. The result was a handle that improved the ergonomics of the iron while maintaining its performance, the purpose of the ergonomic solution was therefore fulfilled.

Design

The design concept was developed using deep interviews and observation which resulted in an iron that solves a pain point for many users. The design of the iron has been altered to blend in with the environment it is used in, designed to be gender neutral and the display could increase its usability all of which increase user experience when ironing. The purpose of the design suggestion was therefore fulfilled.
7. Future work

Throughout the process several areas for future work came up. This since time was limited to twenty weeks and all aspects could not be considered or investigated. Several areas were considered as interesting for the project but was not executed due to limited time but were kept in the background and saved as suggestions for the future. This chapter starts with user study, technical solution, ergonomics, design and finishes of with delimited areas and abandoned ideas.

User study

This section has been removed due to confidentiality.

The study could also be broadened to other countries in order to reach a larger market and get a more accurate solution for all possible users. This since Electrolux products are sold all over the world and this solution is based on a majority of Swedish users’ needs and behaviours.

Technical solution

This section has been removed due to confidentiality.

Ergonomics

The ergonomic evaluation would benefit from additional evaluation testing method as an ergonomic simulation with the program JACK or an Electromyogram (EMG) testing to see which muscles are activated while ironing to exclude bias and validation errors.

Design

The design concept was a suggestion and its construction has not been validated for production. The design after an evaluation would therefore presumably not look the same as the suggestion.

The design concept was created based on a specific style of interior. This style could be investigated further and confirmed with trends on market and Electrolux brand portfolio. The design could also be investigated with user tests where the user get to say which of the design concepts they like the most and what they do not like about them.

Delimited areas and abandoned ideas

Throughout the process several areas of potential or interest were discovered but abandoned due to limited time due to the amount of research they would require. Some of these ideas
would be for example to charge the iron through wifi, put a cloth on top of an induction stove and iron there as the iron would use the induction to generate heat and having an app to connect to the iron and be able to make sure the iron is turned off after leaving the home. Several of these ideas appeared when trying to solve problems users experienced with the cord and the iron board, which both had been set as delimitation for the project.

Another delimitated area was the materials of the iron. *This section has been removed due to confidentiality.* One could though imagine that the iron would consist of recycled plastic as Electrolux products have used this material before and it could be of interest for this project as well.
This Section presents the list of reference presented in an alphabetic order.


DXD. 2016. How to apply a design thinking, hcd, ux or any creative process from scratch. DXD. https://medium.com/digital-experience-design/how-to-apply-a-design-thinking-hcd-ux-or-any-creative-process-from-scratch-b8786efb812 (Extracted 2018-01-16)


Appendix

This section presents the appendixes in the order they are mentioned in the report

Appendix A: Time plan
Appendix B: History line of irons
Appendix C: Pictures of patent
Appendix D: Result Investigation of current solutions
Appendix E: Survey Questions and Data
Appendix F: Observation scrips and summary
Appendix G: Deeper interview
Appendix H: Customer journey mapping
Appendix I: Brainstorming
Appendix J: Mood Boards
Appendix K: Result quantitative test
Appendix L: Script qualitative ergonomic test
Appendix M: Model of 3D printed iron
Appendix A: Time plan

Appendix A presents the time plan created for the master thesis with activities estimated in time of days and a summation of how many weeks in total the project used.

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<th>Activity</th>
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</tr>
<tr>
<td></td>
<td>Report: Document process, First generated concepts, elimination matrix, connect to done research</td>
<td>100%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 week</td>
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<td></td>
<td>5</td>
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<tr>
<td>Phase 4, Deliver</td>
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<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Create prototype 1</td>
<td>100%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Perform tests of prototype 1</td>
<td>100%</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Compile collected data</td>
<td>100%</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Update functions analysis</td>
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</tr>
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<td></td>
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<td></td>
<td>Joint review with Electrovers</td>
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<td></td>
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<td>Analysis of prototype 1 for prototype 2</td>
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<td></td>
<td>Create mood boards for design</td>
<td>100%</td>
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<tr>
<td></td>
<td>Perform tests of prototype 2</td>
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<td>Compile collected data</td>
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<td></td>
<td>Idea generation for design</td>
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<tr>
<td></td>
<td>Update functions analysis</td>
<td>100%</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Report: Document process</td>
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<tr>
<td></td>
<td>Joint review with Electrovers</td>
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<td>1 week</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>Create proposal of final concepts incl. ergonomic, functional and design proposal</td>
<td>100%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Create CAD for final design</td>
<td>100%</td>
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</tr>
<tr>
<td></td>
<td>Create final functional and ergonomic prototype</td>
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</tr>
<tr>
<td></td>
<td>Test final prototypes</td>
<td>100%</td>
<td>8</td>
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<tr>
<td></td>
<td>Compile collected data</td>
<td>100%</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Create suggestions of improvements based on compiled data</td>
<td>100%</td>
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</tr>
<tr>
<td></td>
<td>Joint review with Electrovers</td>
<td>100%</td>
<td>1</td>
</tr>
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<td></td>
<td></td>
<td>3 Weeks</td>
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<td>Render images of product</td>
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<td>Finalise model</td>
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<td></td>
<td>Create presentation</td>
<td>100%</td>
<td>3</td>
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<td>Create opposition</td>
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<td>Opposition presentation</td>
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<td>Time left</td>
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<td>-10</td>
</tr>
<tr>
<td></td>
<td>in weeks</td>
<td></td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>Total weeks</td>
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<td>22</td>
</tr>
</tbody>
</table>
Appendix B: History line of irons

Appendix B presents a history line of irons design and a figure reference list to the figures of the history line.
Figure reference list to the timeline.

5. Steam iron - http://www.bbc.co.uk/ahistoryoftheworld/objects/7F2qaHKRRUW40clPPogwuA
7. Dry iron - https://www.flickr.com/photos/32089334@N08/4189296798
8. Lime scale collector - https://www.youtube.com/watch?v=v01cf6hlGzs
Appendix C: Picture of patents

Appendix C presents the result of conducted patent search in pictures.

Some sections have been removed due to confidentiality.

Tilting handle

Illustration of how the body is tilting versus the soleplate (WO Patent No. 2004085732, 2004).

Fan for drying fabric from moisture

**Detachable soleplate**

Appendix D: Result Investigations of current solutions

This section has been removed due to confidentiality.
Appendix E: Survey Questions and Data

Appendix E presents the setup of the survey, the answers in diagrams and a summary of the answers from the option "other". The survey was distributed in the network community groups "Rent & Snyggt - Städstips" and "Städa rent och ta bort fläckar miljövänligt" on facebook.com which together had 32,000 members. The survey was completed in Swedish and showed in Swedish below and answers have been translated into English.

Survey:
Hej!
Vi gör en undersökning till vårt master examensarbete om strykningsvanor i Sverige. Vi skulle uppskatta om du kan hjälpa oss genom att svara på 10 enkla frågor.
Ditt bidrag kommer underlätta i vårt arbete att försöka förbättra dagens strykjärn.

Tack så mycket! ;)

Vänliga hälsningar
Emilia och Kristin
KTH

1. Kön
   Kvinna
   Man
   Vill ej ange

2. Ålder
   0-20
   21-30
   31-40
   41-50
   51-60
   60+

3. Hur ofta stryker du?
   Varje dag
   En till två gånger i veckan
Någon gång i månaden
Några gånger om året
Aldrig

T-shirt
Skjortor
Byxor
Barnkläder
Jackor
Blusar
Gardiner
Dukar
Annat

Steamer
Torrstrykjärn
Ångstrykjärn
Strykjärn med ångstation
Separat vattenspray
Annat

Pris
Effekt
Utseende/Design
Utplacering av strykjärnets funktioner
Märke
Ångkapacitet
Vikt
Annat

7. Hur lång tid får det ta att stryka en skjorta?
1 min
2 min
8. Jag vill att mitt strykjärn ska... Flera svar möjliga.
    ha automatisk ånga
    låta mig välja när ångan ska appliceras
    vara lätt
    vara tungt
    ha automatisk temperatur
    låta mig ställa in temperaturen
    ha vattenspray
    Annat

    Lätt
    Roligt
    Avslappnande
    OK.
    Tidskrävande
    Tråkigt
    Svårt

10. Att stryka vore bättre om... Flera svar möjliga.
    strykjärnet lämnade tyget torrare efteråt
    det tog mindre tid
    strykjärnet var lättare att förstå
    strykjärnet var mer ergonomiskt
    strykjärnet var snyggare
strykjärnet inte var så varmt
strykjärnet spelade musik
strykjärnet gör att kläderna doftar gott
Annat, vad?

Tack för din medverkan!

*Summary of answers:*
Other:
19 dresses
41 = 21 pillow case + 20 sheats
8 sowing
18 towels
4 pearl crafting
Other:

No coherency, confusion what kind of iron they have. Steam station and steamers are confused for steam irons.

Other:

83 gift or inherit
9 best in test
3 safetymode
5 agile
4 long cord
Other:

7 No cord or longer cord
6 automatic turn off
3 more ergonomic
1 ionized steam
Other:

16 iron board problems
9 cord problems
8 No creases because or iron or coming back when cooling
Appendix F: Observation script and summary

Appendix F presents the setup of the observation Part 1 and 2 with script and summary. Each participant got the same instructions and got to use an Electrolux 5Safety iron which also have been used as reference product throughout the process.

Observation – Part 1

Script

"Welcome! We are interested today to see when you use this Electrolux 5Safety steam iron. If it is okay, we will be filming the observation? Mostly we will look at how you use the iron to find things that we can improve".

"You will iron these three cloths of 100% cotton, the iron is only plugged in at the moment, so you will have to set the temperature. You get to decide how you complete your ironing, but you have steam and spray in the iron and a separate spray bottle here. There is no right or wrong way to complete the task so feel free to do as usual. Iron each cloth until you are satisfied, and we will finish of with asking some questions.

Follow up questions:

- How did you decide when you were done?
  - Why, why, why, why and why...?
- Why did you choose to use these functions on the iron?
  - Why, why, why, why and why...?
- Where or from whom did you learn to iron?
  - Why, why, why, why and why...?
- Why did you choose to not use XX function?
  - Why, why, why, why and why...?

Summary of interview and observation

Gained insight: Important = Blue, Very important = Green

Participant 1

This section has been removed due to confidentiality.

Participant 2

This section has been removed due to confidentiality.

Participant 3 (have never ironed before)

This section has been removed due to confidentiality.
**Participant 4** Rarely ironed before

*This section has been removed due to confidentiality.*

**Participant 5**

*This section has been removed due to confidentiality.*

**Observation part 2**

*This section has been removed due to confidentiality*
Appendix G: Deeper interview

Appendix G presents the setup used for the deeper interviews made about ironing habits. The interview consisted of 26 questions sectioned up into the areas background, ironing habits, storage, use, after use and closing.

INTERVIEW SETUP – Ironing habits

Start by presenting what the project is about.
Ask about documentation, photos, audio etc and explain what it will be used for
Explain that there’s no right or wrong, no pressure on the interviewees etc.

Background
Age:
Gender:
Occupation:
Type of home (apartment, house etc):
Type of iron:
Chose this iron because:

Ironing habits
What do you usually iron?
How often do you estimate that you iron?
What do you think about ironing?
Why do you iron?
Why is this important to you? (to get a further explanation to the reason given before)

Storage
Where do you keep your iron??
   Why do you put it here?
   Why do you put away the iron?
Where do you keep your iron board?
   Why do you put it here?
   Why do you put away the iron board?
Are these locations close to each other in your home?
Would you consider keeping your iron and iron board out until you use next time? Why or why not?

Use
Where do you iron? Why do you iron here? Always same place?
Do you do something else while ironing? For example, watch tv or listening to music? Why or why not?
What is the best with your iron? Why?
What is problematic with your iron? Why?
What does your iron look like?
If you could add one feature to your iron and iron board, what would that be?

After use
For how long do you let your iron cool before you put away your iron and iron board? Do you put them away at the same time? Why?
Would you recommend your iron to others?
If you would get new iron today, what would you look for?

Closing
Do you have anything else to add?
Can we contact you for follow up questions?

Thank you!
Appendix H: Customer journey mapping

Appendix H presents the customer journey mapping created based on the three personas "Minimalistic Marcus", "Career focused Anna", and "Sustainable Madeline". The personas were in turn based on findings from surveys, observations and interviews.

<table>
<thead>
<tr>
<th>Event</th>
<th>Anna</th>
<th>BEFORE</th>
<th>DURING</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Keep wrinkled clothes in the laundry room.</td>
<td>Takes out board and place it close to family.</td>
<td>Steam boosts out lime scale.</td>
<td>Irons towels and clothes if time left.</td>
</tr>
<tr>
<td></td>
<td>Takes out iron and position it on board.</td>
<td>Takes out the laundry and place it on a near by chair.</td>
<td>Starts with delicate clothes thicker fabrics.</td>
<td>Puffs out excessive moist.</td>
</tr>
<tr>
<td></td>
<td>Takes out the laundry and place it on a near by chair.</td>
<td>Brings a tin with narrow nozzle that to fill the water tank in an easier way.</td>
<td>Increases temp and use auto steam.</td>
<td>Turns off iron and let it cool down on board.</td>
</tr>
</tbody>
</table>

| Emotion | Can iron everything at the same time. | Nice with company when ironing. | Use steam puff, it feels ineffective due to lime scale build-up. | Nice to be done with the essentials. |
|---------| Can iron everything at the same time. | Nice with company when ironing. | Use steam puff, it feels ineffective due to lime scale build-up. | Nice to be done with the essentials. |
|         | They are hidden from others to see. | The tap usually miss the water tank opening and spill water. | Lime scale has ruined clothes before. | Nice to be with family while iron is cooling. |
|         | Annoying to walk several times | |

<table>
<thead>
<tr>
<th>Need</th>
<th>Mobility. Being able to decide for themselves where to iron. Wants to combine it with other activities even though it adds time to the process due walking back and forth.</th>
<th>An efficient and more ergonomic Iron</th>
<th>A good looking iron and board that fits the interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td>Ironing habits</td>
<td>Ironing aids</td>
<td>Water prep</td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>Before</td>
<td>Takes turns on who in the family that should iron.</td>
<td>Takes out ironing board to living room and turns tv on.</td>
<td>Refills her separate water spray and iron.</td>
</tr>
<tr>
<td>Action</td>
<td>Takes turns on who in the family that should iron.</td>
<td>Takes out ironing board to living room and turns tv on.</td>
<td>Refills her separate water spray and iron.</td>
</tr>
<tr>
<td>Emotion</td>
<td>Nice to share the responsibility</td>
<td>Takes the opportunity to watch tv-shows she has missed</td>
<td>Takes the opportunity to watch tv-shows she has missed</td>
</tr>
<tr>
<td>Event</td>
<td>BEFORE</td>
<td>DURING</td>
<td>AFTER</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>Action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating dinner and wash the dishes.</td>
<td>Takes out iron and board</td>
<td>Fills the iron full with water.</td>
<td>Hangs the iron right away. Collects them all on hangers before moving them to the closet.</td>
</tr>
<tr>
<td>Wash the clothes and tumble dry in an iron dry moisture.</td>
<td>Turns on the iron and fetch the clothes that need ironing.</td>
<td>Has to put away the iron each 20 sec to adjust the cloth.</td>
<td>Turns off the iron and positions it on a table nearby to cool off.</td>
</tr>
<tr>
<td>Irons directly when laundry is done or hangs it and irons it later.</td>
<td>Positions the wrinkly clothes on the couch.</td>
<td>Use steam in the iron to remove creases.</td>
<td>Puts away the iron board in the cleaning closet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>BEFORE</th>
<th>DURING</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nice to have it tidy and be ready for next task. Nice to iron right away so no laundry will be in the way.</td>
<td>Annoying to walk back and forth.</td>
<td>He has only one pill left, needs to buy more.</td>
<td>He wants to have it tidy. Annoying to remember to put it away later.</td>
</tr>
<tr>
<td>Annoying to have the wrinkly clothes hanging in the apartment.</td>
<td>Annoying to have the wrinkly clothes hanging in the apartment.</td>
<td>He has only one pill left, needs to buy more.</td>
<td>He wants to have it tidy. Annoying to remember to put it away later.</td>
</tr>
<tr>
<td>Needs to stand close to wall with short iron cord.</td>
<td>Wants distilled water but does not have energy to buy it.</td>
<td>Nice to be done.</td>
<td>Nice to be done.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>BEFORE</th>
<th>DURING</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An agile and efficient iron that enables a clean surrounding.</td>
<td>The ironing flow must not be interrupted. The product should feel professional.</td>
<td>Easier to put away when done. Fewer steps to complete the task.</td>
<td>The iron is still not cool enough to put it away.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>BEFORE</th>
<th>DURING</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
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<td>Has to put away the iron each 20 sec to adjust the cloth.</td>
<td>Turns off the iron and positions it on a table nearby to cool off.</td>
</tr>
<tr>
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<td>Use steam in the iron to remove creases.</td>
<td>Puts away the iron board in the cleaning closet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>BEFORE</th>
<th>DURING</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
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<td>Wants distilled water but does not have energy to buy it.</td>
<td>Nice to be done.</td>
<td>Nice to be done.</td>
</tr>
</tbody>
</table>
Appendix I: Brainstorming

Appendix I present the material and presentation used for the brainstorming with trigger material and pictures for inspiration and a summary of the most interesting result from each category.

<table>
<thead>
<tr>
<th>Handle</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buttons position</td>
<td>TOP</td>
<td>SIDE</td>
<td>TOP</td>
<td>SIDE</td>
</tr>
</tbody>
</table>

**Handle**

- Creates strain on wrist

**Button Position**

- **Functions**
  - Button 1 - thermostat
  - Button 2 - ON/OFF
  - Button 3 - Ø
  - Button 4 - Ø

- TOP          SIDE

This section has been removed due to confidentiality.
This section has been removed due to confidentiality.
Appendix J: Mood Boards

Appendix J shows larger versions of the mood boards created to describe the Electrolux brand, the context the iron will be used in and the design guidelines. At the end of the appendix a reference list of the figures is presented.
Figure reference list

Electrolux:


From www.unsplash.com

- Waterfall: John Gibbons
- Tree House: Chris Barbalis
- Ipad: Jeff Sheldon
- Mom: Julie Johnson
- Window house: Roberto Nickson
- Pillars: Mirko Blicke
- Friends: Helena Lopes
- Plants: Markus Spiske

Context:


Bsqab - http://www.besqab.se/bostaeder/intresseanmaelan/stureby/bilder/

Veidekkebostad - https://veidekkebostad.se/sveaserenad/?source=hemnet&utm_source=hemnet&utm_medium=objekt&utm_campaign=Svea%20Serenad%2C%20%C3%96stermalm#images

Ikano Bank – Trivas - https://ikanobostad.se/kopa-bostad/Brf-Trivas/

Set table: Grovemade www.unsplash.com

Design:


Light - http://www.muji.com/uk/about/


Coffeemachine - http://1.bp.blogspot.com/_AxQ_nteGNe/S8LbI95R1I/AAAAAAAAAhE/Mn2QwFAVuX4/s1600/glass_kettle2.jpg


Drops - http://1.bp.blogspot.com/_AxQ_nteGNe/S8LbI95R1I/AAAAAAAAAhE/Mn2QwFAVuX4/s1600/glass_kettle2.jpg
Thermos - http://www.alltombostad.se/basta-nyheterna-fran-stelton-2016-2465/blog.html


Ceramic vase - https://confidentliving.se/sv/p/kruka-natur-terrakotta-175-cm

Leather - https://scontent-sea1-1.cdninstagram.com/vp/1b97ecb2877faa39749cf8fe58488918/5B305C8B/t51.2885-15/e35/12825861_174300339618834_388967219_n.jpg?se=7&ig_cache_key=MTIwMTYwODM4NzYyNzAzMDQzMw%3D%3D.2


Water boiler - https://www.rum21.se/bilder/artiklar/zoom/1041298_2.jpg


Computer stand: Grovemade - www.unsplash.com
**Appendix K: Result quantitative test**

*Appendix K presents the result of conducted quantitative test.*

<table>
<thead>
<tr>
<th>Height</th>
<th>Woman</th>
<th>Angle Handles</th>
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**Note:**
- Angle Handles: Red, Blue, Purple
- Sum of all rows equal to 14 for both women and men.
Appendix L: Script qualitative ergonomic test

Appendix L presents the script used when conducting the qualitative ergonomic tests.

Material: 3 irons, wrinkly shirts, iron board, notepad, timer, body maps, Borgs C10 scale.

Preparation: Have the original iron plugged in and ready to use. Hide the other two. Lay the wrinkly shirt on the board.

The test: Present how you are going to approach the user when doing the test.

1. Present the Borgs and body map
2. Tell them that they are going to iron for 4 min and that when they are halfway through we will ask them where and how much they feel in the body
3. Ask them to set the height of the iron board and measure it.
4. Tell them to start and that we will ask some questions meanwhile.
5. 2 min in ask about body map and borg’s scale, mark with one colour pen.
6. 4 min and done, ask them again about body map and borg’s scale, mark with other colour pen.
7. Then ask them again after every 30 seconds until the pain is gone.

First iron with original handle will be used with heat, then the 30° handle iron and lastly the handle with 50°, both without heat.

Heat is used in the first to get a feeling of how to iron and how long time they spend of each area.

Questions to ask meanwhile
* Where do you iron at home?
* With what iron?
* Do you do something else while ironing, for example watching tv or listening to music?
* Where do you store your iron and iron board?

Ask them afterwards
* Which one did you prefer and why?
Appendix M: Model of 3D printed iron

Appendix M presents how the hand posture changes when holding the developed product.