CHALMERS

Medical Cooler

Development of a modern medical cooler for personal use

Master of Science Thesis in Industrial Design Engineering

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Cover:3D render of the final design concept *Away*.

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ABSTRACT

The focus of the master's thesis is to design a medical cooler for personal use with improved cooling capacity and improved reliability. The product segment was highlighted by friends prescribed with temperature sensitive biopharmaceuticals as to some extent reduce the quality of life. The mentioned experiences regarding the product indicated a product segment with poor performance and aesthetics. The insufficient cooling capacity of the medical coolers was especially experienced on long duration travels. It had sometimes lead to a state where the medication, which are to be taken regularly, was left at home during the sojourn even though the health was put at risk.

The product development was approached by an iterative process, which was initiated with a thorough literature and user study in order to define the system surrounding the product and the demands put on the medical cooler. Several concepts of medical coolers were created in order to explore, study and identify the different areas of potential product improvements. The concepts were analysed and evaluated using prototypes and other methods in order to select a final concept. As the final concept was translated from sketches to CAD models the concept went through an iterative refinement process. In order to properly evaluate the cooling capacity and user experience of the final concept, a functional prototype was created.

The final concept, *Away*, features a reliable medical cooler specifically designed for injection pens with biopharmaceutical substances. *Away* possess an improved design that extends the cooling time and enhances the overall user experience both by intuitive layout and appealing appearance. The design of *Away* is adapted to the use scenario of aircraft travelling and is developed to be easy to handle during the entire travelling scenario.

The findings of the master's thesis indicate that there is great potential of improving the cooling capacity and user experience within the area of medical coolers. The thesis also demonstrates the possibility to take an important step towards improving the everyday life and patient security for users prescribed with biopharmaceuticals.

Key words: Medical Cooler, Assistive Products, Travel by Air, Biopharmaceuticals, Product Design

PREFACE

This report is the documentation of a master's thesis for a Master of Science in Industrial Design Engineering at Chalmers University of Technology in Gothenburg, Sweden. The thesis was carried out during the spring of 2013.

The idea of the project started to emerge during the summer of 2012 during a conversation with friends who are in need of taking biopharmaceutical medicines regularly due to their chronic diseases. Due to their treatments they need to bring a medical cooler when travelling for a longer period of time. After consulting the pharmaceutical companies AbbVie and Biogen Idec the need of an improved medical cooler was verified. The complex of problems associated with the coolers designed for transporting medicine on travels evoked the desire to improve the product and thereby patients with chronic diseases' quality of life.

Acknowledgements

First of all, we would like to thank all the participants of our research and evaluation as well as Frida Edberg at Unga Reumatiker and Fia Gunnarsson at Neurologiskt Handikappades Riksförbund (NHR) for support in finding participants and help regarding the distribution of the user survey. We would also like to send our gratitude to the representatives from AbbVie and DS Smith Packaging who all provided us with important input in our quest to develop a successful product.

We would like to thank our supervisor Lars-Ola Bligård and Oskar Rexfelt at Chalmers University of Technology, who great interest in the project and gave us valuable input and guidance.

Sofia Alvenby & Mikaela Rehnmark
Gothenburg, 29th of May 2013

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1 INTRODUCTION

Industrial designers have the possibility to create products that enhance and improve user's quality of life. A product segment that was highlighted by friends prescribed with temperature sensitive biopharmaceuticals as to some extent reduce the quality of life was the segment of medical coolers for personal use. The mentioned experiences regarding the product indicated a product segment with poor performance and aesthetics. The insufficient cooling capacity of the medical coolers, especially on long duration travels, had sometimes lead to a state where the medication, which are to be taken regularly, was left at home during the sojourn even though the health was put at risk.

The medical coolers available today usually guarantee to keep the required temperature for about 6-12 hours. According to SAS, the flight duration from Stockholm to New York is about 12 hours, which makes it nearly impossible to carry out the travel without the risk of damaging the medication.

The need of an improved medical cooler is also a way to keep up with the field of clinical evidence and pharmaceutical knowledge, which has developed rapidly over the years. The development has enabled more effective and safe treatments, which have given the patients with for instance chronic diseases an essential brighter future with an improved quality of life.

As flexibility and mobility has grown to become an important part of our everyday life, both regarding work and leisure time, the medical coolers was regarded as one of the key products to improve the everyday life and patient security.

1.1 THE PROJECT

1.1.1 Purpose

The purpose of the master's thesis is to design and develop a medical cooler with improved cooling capacity in order to simplify travelling for users who are prescribed with biopharmaceuticals.

1.1.2 Aim

The thesis will result in a final concept of a new medical cooler for personal use with improved design that extends the cooling time and enhances the overall user experience. The final concept aims to fulfil the following aspects:

- Possess an improved cooling capacity compared to competitors' products.
- Deliver an intuitive and user friendly design that follow anthropometric data and ergonomic guidelines.
- Be realisable within the next three years.
- Created in a sustainable manner in order to reduce the environmental impact.
- Reduce the overall environmental impact of the product.
- Competitive price level.
- Fulfil the existing basic characteristics of the competitors' products.

1.1.3 Deliverables

The thesis' deliverables will be a new concept of a medical cooler, which will be presented in the following manners:

- High detailed CAD models with accurate dimensions and materials.
- A prototype with high degree of functionality and aesthetics.
- Manufacturing specifications and blueprints.
- Photo-realistic renderings and/or visualisations.

1.1.4 Requirements

In order to deliver a successful design, the product should meet the set of requirements defined during the pre-study. However, the following requirements and aspects are regarded as key factors and shall therefore be implemented into the final design:

- Hold temperature sensitive medicine.
- Meet the regulations and guidelines associated with the use scenario.
- Be able to carry sufficient medicine for the entire sojourn.

1.1.5 Limitations and Delimitations

A key aspect of the thesis is to study the travel scenario of airline flights since travelling by flight have the most restricted regulations concerning liquid medicine handling. The main limitation that originates from the scenario is the different airlines' regulations regarding liquid medicine and carry-on luggage. Since there are several companies in the airline industry, there will not be time efficient to study all of them and the thesis is therefore delimited to study the regulations and guidelines by International Air Transport Association (IATA), Transport Security Administration (TSA) and Transportstyrelsen. The travel scenarios of interest will include cases with travel durations within 24 hours, including durations for travel to the airport, flight and possible transfer.

The project will study users that have been prescribed with biopharmaceutical medicines that need to be cooled in the temperature range 2-8°C and who need medicine regularly during their sojourn.

Cost calculations will not be part of the project scope. However, since the aim is to target a competitive price level the costs will not be allowed to become unreasonable.

1.1.6 Sustainable Design

Sustainable development will be used as an evaluation criterion with high priority when deciding upon concept and materials. An important aspect when deciding how to implement sustainable design into the thesis is the fact that the product is not aimed to be a short-lived product. The aim is to create a durable product with long lifetime both concerning the thermal technology and the overall design of the product. The end-of-life phase in the product's life cycle should be considered during the ideation phase both concerning the selection of materials and waste management. The selection of materials should to a large extent coincide with sustainable development but the choice will also be a consideration of cost and material properties.

Computer calculations of a simulated manufacturing scenario will be performed to estimate the environmental impact of the selection of materials and manufacturing processes.

2 METHODS

The selection of methods and tools were focused on eliciting user demands and to gain an understanding of the product and its context and to be able to analyse the gathered input in a manner that would benefit the product and ultimately also enhance the user experience and quality of the product.

This chapter contains descriptions of the process of the master's thesis as well as explaining which elements that were included in each phase of the process. The methods and tools used throughout the project are described with their purpose, goal and a description of when and how they were utilised in the project.

2.1 PROCESS

The process of the master's thesis was based upon an iterative product development model similar to the one presented by Johannesson et al. (2004), which include the iterative stages of *problem definition and analysis*, *synthesis* and *analysis*. The process' stages could also be described as the 4-D model, which according to Maylor (2010), is commonly used by project managers; *Define it*, *Design it*, *Do it* and *Develop it*. The master's thesis began with the initiation of the planning stage where the project was defined and then followed by the design of the project and its process. The project then entered the Do and Develop phases. However, in order to organise the project, the Do and Develop phases as well as the other stages and phases by aforementioned authors were transformed into five phases; *Pre-study*, *Usage Design*, *Ideation*, *Final Concept & Visualisation* and *Summary & Documentation*.

Each of the phases possessed a quantitative character in its beginning and developed through iterative cycles into a more qualitative character in order to fulfil the set goals of each phase and thereby be finalised. The documentation was conducted throughout the project and was finalised by the submission of the master's thesis report and presentation.

The time plan of the master's thesis can be found in Appendix I. Time Plan.

The following sections describe the process, area of focus, goal and methods conducted during of each of the five phases.

2.2 PRE-STUDY

2.2.1 Process

The initial phase's focus was to define the demands of the product and to gain an understanding of the system surrounding the product, such as its purpose, users and context. The phase also included a competitor analysis to identify different kind of medical coolers, current trends and functionalities. Concurrently with the competitor analysis, research of thermal technology and materials were performed as well as research concerning regulations from influencing instances. The gathered information was compiled into a list of requirements and user inputs, which was used as foundation in the following phases.

2.2.2 Methods

Literature Studies

Literature studies were performed to gain an insight to the area of interest, background, influencing regulations and research. The literature was obtained through statistics databases, academic literature, articles, Internet forums, websites etc.

User Studies

It was important to perform a thorough user study in order to identify the different users and their unique attributes. The user study consisted of interviews, observations and surveys in order to gain a holistic view of the users. The user study was mainly performed in the first phases of the project. However, complementary interviews and observations were conducted later in the project. The purpose of the user studies was to identify user demands and desired attributes of the product domain in order to translate them into requirements. According to Sutcliffe (2002), the elicitation of user requirements may be conducted using the following techniques; interviews, focus groups, observations, surveys and reviewing documentation. The techniques used in the project are listed and described below.

Interviews

Interviews were conducted with pharmaceutical companies, packaging companies and primary users in order to gain a holistic view as well as detailed information concerning the area of interest. Additional e-mail conversations were held with airline companies as their regulations were found to impact the use of the product. E-mail conversations were also held with experts within thermal technology and pharmacists in order to evaluate ideas and to gain expert knowledge in the area.

The interviews with representatives from the pharmaceutical and packaging companies were of semi-structured character in order to obtain both qualitative and quantitative information (Karlsson, 2009) and were recorded in written text. The interviews were held at four separate occasions, two with each company, during the two first phases.

The user interviews were conducted with five users and were performed in order to complement the surveys. The characteristics of the interviews were therefore semi-structured, which allowed discussion and probing with the participants (Karlsson, 2009). Two of the interviews were held as a small focus group whereas the other three were held with each participant privately. All five participants were theoretically representative since they had similar demographics, experiences as well as physical and cognitive abilities as the primary user group (Karlsson, 2009). The interviews were all held in January and February of 2013.

Observations

Observations were performed in order to gather visual data of how the current competitor products were handled by the user as well as how they are manufactured. The observations were therefore performed with both primary users and packaging manufacturers. Observations as technique enable the identification of physical information as well as information concerning the context, exceptions to the usage and "work-arounds" of the normal handling (Sutcliffe, 2002). The observations were performed during the two first phases of the project and were recorded in written text as well as photographs.

Surveys

Two surveys were conducted in order to gain insight of the user's perspective of the product. One survey was compiled in Swedish for a domestic respondent group whereas an English survey was constructed to reach an international crowd. The surveys were both conducted as online surveys and were posted on forums and in digital newsletters by national organisations for the targeted primary users. The questions in the surveys were of both open-ended and closed character in order to gather both qualitative and quantitative data (Sutcliffe, 2002).

The respondents of the survey were theoretically representative for the primary user group as they all were potential users of the product and met the set requirements of being a primary user (Karlsson, 2009). The amount of respondents was 27, which

according to Griffin and Hauser correspond to the possibility of identifying up to 90% of the users need (Griffin and Hauser, 1991). The surveys were both recorded as written text and as diagrams and tables.

Competitor Analysis

A competitor analysis was conducted with focus on trends, key success factors and competitors' products in order to map and identify opportunities for improvements (Bergman and Klefsjö, 2010). The analysis, so called benchmarking, was performed in order to create a basis for the further development. The analysis included research regarding different products and manufacturers and also regarding the concerned thermal technology of each competitor product. The competitor products were compared to each other and the analysis resulted in insights and guidelines of how to proceed with the product development.

Material Analysis

A material analysis was performed in concurrence with the literature study concerning thermal technology in order to analyse which materials that could potentially be used in the product concept. The material analysis was based on the data collected in the literature study and through interviews with experts. Part of the material analysis was also conducted through the software CES EduPack to be able to obtain comparable data regarding the product's set requirements.

2.3 USAGE DESIGN

2.3.1 Process

The focus of the second phase was to study different users and user scenarios in order to gain a holistic view of the product's operators and operating environment. The outcome of the phase was requirements and guidelines regarding the usage, which was added to the list of requirements.

2.3.2 Methods

Observations

Additional observations of a simulated use scenario were held in order to study the usage further and to explore ideas and usage related factors which could influence the design. These simulations were held with a fellow student at the master's programme, who were introduced to the use scenario and then asked to simulate the handling of the medical cooler.

Storyboard

To be able to communicate the identified usage scenarios a storyboard was created. The storyboard aimed at describing the use scenario and environment as well as describing common identified problems of the current solutions.

Persona

Two persona were created in order to communicate potential users of the product. The persona were based upon findings from the user studies and literature studies and aimed at representing the target user group. The persona also worked as a tool to understand the user group and their motivations, behaviours, abilities and expectations of the product.

Hierarchical Task Analysis

An Hierarchical task analysis (HTA) was performed in order to design and illustrate how the users in an ideal case were to use the concepts as well as the final concept but also with aim to structure the handling and gaining knowledge of the usage (Bohgard et al., 2008). By dividing the tasks performed during the handling of the products the relations and dependencies between the sub-tasks were identified. The results then lay as basis for the designing of the usage of the concepts and finally the product concept. The method was used in the end of the second phase as well as during the third phase.

Affinity Diagram

An affinity diagram, also referred to as the KJ-method, was conducted in order to structure the data from the user studies and these were then translated into requirements and design guidelines (Bergman and Klefsjö, 2010). The qualitative, verbal data were gathered and sorted into categories depending on the content. Each group of data was then analysed in order to obtain requirements and guideline for the continuous development (Karlsson, 2009). The analysis was performed in the end second phase in order to compile findings from both the first and second phase of the project.

Requirement Specification

The outcomes of the pre-study and the usage design phase were identified user demands on the product, but also an increased understanding of the implications of the usage domain and what could be applicable for the desired product (Sutcliffe, 2002). These inputs were transformed and compiled into a requirement specification. The specification list contained both requirements and guidelines regarding the demands as well as desired attributes. The list also contained measures, importance and additional comments. The specification was constructed during the first and second phase in order to capture the requirements as they were identified.

2.4 IDEATION

2.4.1 Process

The ideation phase was guided by the identified requirements and guidelines from the aforementioned phases. The ideation phase included three main tasks; concept ideation, visualisation and prototyping, which were conducted simultaneously during the phase. The concept ideation generated a large quantity of concepts. The concepts were accumulated and evaluated, scrapped or combined in order to create a concept that fulfilled the design guidelines and requirements. The phase was a highly iterative cycle of ideation, visualisation and prototyping in order to define a final concept.

2.4.2 Methods

Ideation Triggers

During the phase several ideation triggers were used in order to help generate ideas, for instance Brainstorming and Osborne's idea spurs (Karlsson, 2008). The generated ideas were sketched on paper or written in text in order to keep them visual during the phase.

Sketching

The creation of sketches was performed as an aid to visualise ideas and concepts during the phase. The sketches were thereafter used as foundation for the development of the refined and more advanced visualisations, such as digital 2D and 3D representations as well as prototypes. The sketching sessions were one of the main activities during the phase but were to some extent also used to capture spontaneous ideas that evolved during the first and second phase.

SWOT

The SWOT analysis was performed with the aim to analyse the strengths, weaknesses, opportunities and threats of each early concept in the Ideation phase. The analysis method was used as a tool to gain an overview of the concepts from a more objective perspective (Göteborgs Universitet, 2010). The results of the analysis lay as basis for the evaluation of the early concepts.

Observations

Observations similar to those performed during the usage design phase was performed in order to investigate the concept's advantages and disadvantages regarding carrying manner and handling in the use scenario. These simulations were held with a fellow student at the master's programme, who were introduced to the use scenario.

2.5 FINAL CONCEPT & VISUALISATION

2.5.1 Process

The fourth phase began with the defining of the final concept. The final concept was then subject to evaluations and refinements before a prototype was built and validated. The concept was refined through CAD models and was later on evaluated by users regarding its design and usage. The final concept was also evaluated from an environmental and manufacturing perspective using computer software.

2.5.2 Methods

Digital Visualisation

Digital visualisation was conducted in order to capture and describe the concepts in more detail. Both 2D and 3D visualisation were created through the usage of an array of computer software. The 3D models were also created in order to be able to evaluate the sustainability and manufacturability. The digital visualisations were done during the third and fourth phase of the project.

Prototyping

Prototyping was performed in order to evaluate the functionality, dimensions, aesthetic attributes etc. of the concepts and final concept. Initially, functional prototypes, in terms of modifications of existing products on the market, were performed in the Ideation phase in order to explore the possibilities of dimensions and functionality of different materials and cooling media. A final functional prototype was built as a final step of verifying the design, both regarding form and function as well as user perceptions.

Focus Groups

Focus group interviews were performed with six participants to enable the users to discuss the developed concept and prototype. The participants were allowed to interact with the physical prototype as well as reviewing 3D renderings of the CAD models. The focus group consisted of both a discussion and questionnaire which was based on the, according to Bergman and Klefsjö (2010), Quality dimensions of goods as quality was set to one of the most important characteristics of the product. The questionnaire also included a Self-assessment manikin (SAM) evaluation of the product elicited emotions. The method measures the by the user self-experienced emotional states of valence, activation and control (Desmet, 2003). The users were asked to rate the emotional states on a scale ranging from 1-5. The feedback and questionnaire aimed at obtaining input that would strengthen the final concept as well as providing input regarding

further development. The focus group sessions were performed in the Final concept & visualisation phase in order to evaluate the overall design of the product concept.

Radar Charts

Radar charts were used to visualise the results of the focus group evaluations, which were performed in the later part of the project. The radar charts' visual communication allowed a comprehensive illustration of how the final concept was perceived and which aspects of the product that were regarded as prominent respectively needed to be developed further. The scale of the radar charts correspond to those set in the evaluation questionnaires and the plotted values match the mean value of the results.

Streamlined Life-Cycle Assessment

A Streamlined life-cycle assessment (sLCA) was performed in order to analyse and estimate the product's environmental impact throughout its whole life cycle. The method was conducted through the software SolidWorks, which analyses 3D-models based upon their materials, manufacturing methods, manner of transport etc. The method facilitated a simple way to analyse the final concept's impact, which findings thereafter were used as basis for the environmental evaluation in the evaluation stage.

Manufacturing Evaluation

The manufacturing evaluations were performed in the later part of the project to evaluate the selection of materials as well as manufacturing method of the product. The evaluation aimed at studying if the selections were well based or if some adjustments should be carried out in a further development of the product. In order to perform the evaluation, the CAD model of the product was supplied with accurate materials and a simulated manufacturing process were entered in the computer software SolidWorks.

2.6 SUMMARY & DOCUMENTATION

2.6.1 Process

With the final concept finished in the previous phase, the last phase aimed at compiling the documented material throughout the project. These include the written and visual documentation of the design process, summaries of the initial demands and usage studies and other material obtained during the project. The phase's outcomes were the master's thesis report and final presentation.

3 PRE-STUDY

The aim of the pre-study was to gain an understanding of the product, its different users, the context of use and the product's purpose of existence, as these factors construct the system surrounding the medical cooler. Furthermore, the identified requirements and other input from the pre-study will be the foundation for the creation of the product further on.

The pre-study was carried out through literature studies, competitor analysis as well as thorough user studies. The user studies included interviews, surveys and observations of both primary users and other concerned actors within the system such as pharmaceutical companies and packaging companies. The pre-study also highlighted the current competitors and their key success factors as well as investigated different authorities' regulations and requirements regarding the product and its usage. Furthermore, the pre-study included a series of thermal technology testing and use scenario simulations in order to extract input that would benefit the further development of design concepts.

3.1 MEDICAL COOLERS

The following section concerns the product segment of medical coolers as well as a definition of the group of medication that are to be transported within it. In addition to this, the role of pharmaceutical companies and health care regarding the medical coolers is accounted for as well as declaring the competitor analysis and potential thermal technologies.

3.1.1 Product Definition

As the literature study could not point at one solid definition and linguistic term for coolers in which medical substances are to be transported, the following definition were used in the project: A medical cooler is an insulated container which main purpose is to maintain the temperature of medical substances such as biopharmaceuticals. Medical coolers consist of materials with insulating properties as well as cooling media.

Biopharmaceuticals

Biopharmaceuticals are pharmaceuticals which active substance has biological origin (Läkemedelsverket, 2012). The biological substance is produced or extracted from sources such as micro-organisms, protein and nucleic acids (Head of Medicines Agencies, 2012). As these substances are delicate they need to be stored in a temperature range of 2-8°C and are sensitive to light exposure (FASS, 2011). In order to gain expert's input in the area, interviews were held with representatives from the pharmaceutical company AbbVie. According to the interviewees, the degrading of the substances accelerates if the biopharmaceuticals are exposed of temperatures outside the recommended interval, which implies that the medicine needs to be consumed within a short period of time. However, if the medication is frozen the substances may be destroyed (Johansson, M.).

The risk of freezing the liquid inside the pen or syringe was further discussed with a pharmacist at the pharmaceutical company Biogen Idec. According to the pharmacist, the package for each injection pen, see figure 1, contains air in order to insulate the liquid further. The liquid is also protected to some extent due to possessing a temperature of 2-8°C when put in the medical cooler (Ottenblad, A.). According to a survey conducted by Biogen Idec (2013) 9 of 10 users preferred to use injection pens instead of syringes. The literature study has therefore been focused on injection pens. During the literature study it became evident that the size of the packages varies among brands and manufacturers. The dimensions of the packages should therefore be taken into account during the further development in order to be fitted into the product.

FIGURE 1. Package and content of Avonex Pen, by Biogen Idec.

INJECTION PEN

AVONEX PEN PACKAGE

CAP INJECTION PEN NEEDLE

3.1.2 Health Care & Pharmaceutical Companies

The role of the health care in terms of medical coolers is to be the provider of start-up kits to patients prescribed with biopharmaceuticals. The start-up kits include among other things a medical cooler (Biogen Idec., 2008). The pharmaceutical companies responsible for each biopharmaceutical sponsor these medical coolers (Johansson, M.). Representatives for AbbVie state that the cooler bags provided are especially designed for each medication, for instance their medicine Humira.

Medical Coolers from a Pharmaceutical Company's Perspective

During the interviews with representatives for AbbVie Sweden it was stated that they, from a pharmaceutical company's perspective, regard the medical cooler as an important part of the patient security that they want to guarantee with their pharmaceuticals (Johansson, M.). In order for them to guarantee the medication's reliability, the medical coolers need to ensure the correct temperature and it also need to be handled correctly. If the medication is exposed to temperatures outside the recommended interval, the company can't guarantee its efficiency, which in AbbVie's point of view is highly desirable and valuable (Johansson, M.). Further details regarding the interviews with pharmaceutical companies, see Appendix II. Interview Guide Companies.

3.1.3 Competitor Analysis

In the system of interest, the temperature of the content should be kept within 2-8°C, which adds to the complexity and increases the demands on the medical cooler in terms of materials and construction in order to maintain the temperature for the desired period of time with precision and reliability. However, the competitor analysis have focused on products that fulfil the main goal of transporting medical substances and not on whether or not the products meet the exact same requirements as the desired product concept of this master's thesis.

The competitor analysis was aimed at identifying denominators of the competitor products regarding their strengths and weaknesses as well as their appearance, thermal technology and function.

As the main goal of the system is to transport medical substances for personal use, the potential competitors of a product candidate is both other medical coolers as well as commercial food and drink coolers. These products have been divided into two product

FIGURE 2. Cooler bags from AbbVie, Biogen Idec. and Polar Bear Coolers.

COOLER BAGS

categories depending on their product surface; cooler bags that have a soft exterior surface and coolers, which have a hard exterior. Each group of products is described with examples of competitors. A compilation of the competitor product may be found in Appendix III. Competitor Analysis.

Cooler Bags

Cooler bags are coolers that typically have soft exterior and are designed as shoulder bags, totes, cross body bags, ordinary bags, backpacks, duffels or occasionally as suitcases with wheels. The cooling media is most commonly ice packs, dry ice, regular ice or gel. A selection of cooler bags is presented in figure 2 on the previous page and is described in the following paragraphs.

One of the main competitor products in this segment are the cooler bags provided by the pharmaceutical companies. These cooler bags are given to the health care as sponsored products and is received by the patients as they start a biopharmaceutical treatment program. The competitor analysis has focused on the cooler bags sponsored by the pharmaceutical companies Biogen Idec and AbbVie, designed for Avonex and Humira respectively. Mutual characteristics for these cooler bags are their size, cooling capacity, cooling media and colour. The amount of medication that fit into the cooler bags is between 2-3 doses of each targeted pharmaceutical. The cooler bag by Biogen Idec is guaranteed to maintain the required temperature for up to 12 hours in an ambient temperature of 23°C (Biogen Idec., 2012). AbbVie's sponsored cooler bag is said to guarantee 8 hours within the correct temperature (Johansson, M.). Both cooler bags uses gel as their cooling media although in different shapes and sizes. Biogen Idec provides a gel cuff that can be fitted onto the walls of insulation of the cooler bag whereas AbbVie offer a single gel pack. Another similarity between the cooler bags is the choice of colour, as both possess a rather intense and eye-catching colour.

Another identified competitor in this segment of products was found to be the company Polar Bear Coolers. The company offers cooler bags with target markets such as hunting, fishing and medical. After communication with Leslie Woods, representative for the company, it was found that the cooler bags are the same except for the additional features such as a plastic compartment for medicine in the medical aimed cooler bag. The cooler bag is guaranteed to maintain the required temperature for around 12 hours by using the Polar Bear ice packs (TechniIce) or regular ice (Polar Bear Coolers, 2012). The cooler bag is designed as a shoulder bag but can also be transported by using the handle.

Coolers

Coolers or hard coolers as they are sometimes referred, are coolers that are hard shelled and primarily made of plastics. During the competitor analysis it was identified that they in general were of either two types, non-powered or thermoelectric.

The non-powered coolers found on the market today, are typically designed as ordinary boxes or are toolbox-like in their gestalt with a simple plastic or rubber handle. The cooling media is primarily ice packs or regular ice. One identified competitor to represent the product segment of non-powered coolers is the company Igloo Products Cooperation, which offers several coolers and amongst them the recognised trademark Playmate. The Playmate coolers are mainly targeted at markets such as food and drinks and have therefore not a stated cooling capacity or a set guaranteed cooling capacity in the desired temperature range. A common trait in the product segment is that the coolers have a simple, plain appearance and comes in a variety of colours and graphic patterns (Igloo Coolers, 2013).

Within the segment of thermoelectric coolers, two representative of the competitor analysis findings were the companies Dison Electric Cooperation and Igloo Products Cooperation. All thermoelectric coolers possess the trait of having either batteries or motors with power adaptors as their means of energy. Another significant difference towards other cooler alternatives, the thermoelectric coolers often have technical features such as a LCD display and built-in thermometer.

Dison Electric Cooperation offers thermoelectric coolers that are especially designed for medication such as syringes and pens. These coolers are so called micro fridge boxes and are powered by batteries, which have the working time of 12 hours. The box can be transportable by using an especially designed bag (Cool Ice Box Company, 2013).

Thermoelectric coolers that are based on motors with power adaptors were found to more often be larger containers with quadratic appearance and are thereby more bulky and less flexible as other alternatives. However, these coolers are portable in the sense that they possess a carrying handle. These coolers are often aimed at being used in the car, on road-trips or in professional scenarios.

3.1.4 Thermal Technology

The thermal technology of coolers and cooler bags was investigated by consulting and interviewing experts in the area of energy technology and representatives from DS Smith packaging as well as through literature studies concerning the topic. Observations of the manufacturing process and packaging solutions for temperature sensitive payloads were also performed at a field trip to DS Smith Packaging's facilities in Värnamo, Sweden.

According to Preston Williams and Rafik Bishara (2010), in order to optimise the temperature-controlled container, the materials for the outer container, cooling media and insulation need to be determined. The choice of materials for these components is dependent on for instance the volume that is to be cooled, time duration, total volume, total weight, form aspects as well as cost (Williams and Bishara, 2010). The findings of the literature study as well as the interviews and consulting sessions regarding materials that could be beneficial and thereby potential for the medical cooler application are described in the following sections. The materials is also illustrated with some of their important properties in Appendix IV. Material Properties.

Outer Container

For the desired application, some basic demands put on the material for the outer container were for instance durability, price, total weight, a good insulator, water resistance, recyclability or biodegradability and CO_2 footprint. Based on these demands and by using the software CES EduPack and taking properties and facts by Ashby and Johnson (2010) into account, the following materials were found relevant for the desired application:

- Acrylonitrile-Butadiene-Styrene - 0.18-0.33 W/(mK)
- Polycarbonate – 0.19-0.22 W/(mK)
- Polyethylene – 0.12-0.50 W/(mK)
- Polyethylene Terephthalate – 0.28-0.58 W/(mK)
- Polypropylene – 0.11-0.17 W/(mK)
- Polystyrene – 0.12-0.13 W/(mK)

For the further development of the product it is also relevant to take into account the manufacturing process as well as the user experience of the different potential materials in order to create a sustainable and successful product. These aspects are declared more thoroughly in the chapter *6. Evaluation.*

Cooling Media

The demands put on the cooling media used for this application are for instance the cooling capacity and efficiency of the media as well as the price and availability of the media. Another important aspect is the user friendliness and usage associated with the cooling media. During the literature study it was found that, cooling media in general can be divided into the groups phase change materials (PCMs) and thermoelectric solutions. The studied PCMs can be seen in figure 3 on page 27.

Phase Change Materials

According to both the interviewed representatives from DS Smith Packaging and Zalba et al. (2002) phase change materials (PCMs) are widely used as cooling media by transport and packaging companies for transports of temperature sensitive payloads. PCMs are materials which latent heat of fusion is used to maintain temperatures. The latent heat of fusion is the amount of heat required to transform a solid to its liquid phase and vice versa. The use of a solid PCM protects against warmer ambient temperatures whereas liquid PCMs is applicable when protecting against cold ambient temperatures (Williams and Bishara, 2010). The list of PCMs is extensive, however examples of PCMs are water, cooling gel and crystals (Zalba et al., 2002).

According to the consulted Björn Palm, professor and prefect in energy technology at the Royal Institute of Technology in Stockholm, water and its solid phase, ice, are the two materials that provide the least volume and weight to the system compared to other cooling media. However, the temperature in the container then needs to be controlled in other ways than the melting temperature, for instance by providing adequate thermal in-leakage (Palm, B.). Ice as cooling media often requires insulation or air separating the cooling media and the payload. Furthermore, ice cannot protect the payload from cold ambient temperatures. An advantage with the cooling media is that the material is inexpensive, 0.2-0.3$/kg (CES EduPack) and readily available (Williams and Bishara, 2010). Ice and other PCM's can also be used with different additives in order to maintain different temperatures (Zalba et al., 2002).

In similarity with ice, cooling gel packages often need to be separated from the payload by an additional insulation or air column (Williams and Bishara, 2010). Regarding the cooling capacity, gel and ice have similar properties as gel often consists of water with different additives. Cooling gels with additives such as herb extracts are commonly used for applications such as burns, sprains and itching (Apoteket, 2013a). However, these

specific gels are not applicable for the desired product application.

Regarding both ice and gel, an additional insulation need to separate the cooling media and the payload. This can be solved with for instance foam dividers, bubble wrap (Woods, L.), corrugated cardboard (DS Smith Packaging, 2012) or other PCM's with different set temperatures (Ek, M.).

Another group of PCM's is different kinds of crystals. The crystals are either activated manually by for instance putting them in water or they undergo their phase change at a set temperature level. For the desired application this temperature level could very well be 2°C, which thereby will maintain the temperature range 2-8°C for a longer period of time. From an economic perspective, the crystal PCM's are on the one hand more expensive than water but on the other hand, more advanced PCM's save costs by enabling a reduction of insulation between the payload and cooling media (Williams and Bishara, 2010).

Additionally, a type of PCM is the so-called Techni-Ice. Techni-Ice is a dry ice pack based on a refrigerant polymer. According to the manufacturer, Techni-Ice possesses an improved cooling capacity compared to ice and gel packs. The cooling media is inferior to ice packs regarding its price but may be superior regarding its cooling capacity. The media is readily accessible on the market. (Global National Australia Pty Ltd, 2012)

Thermoelectric

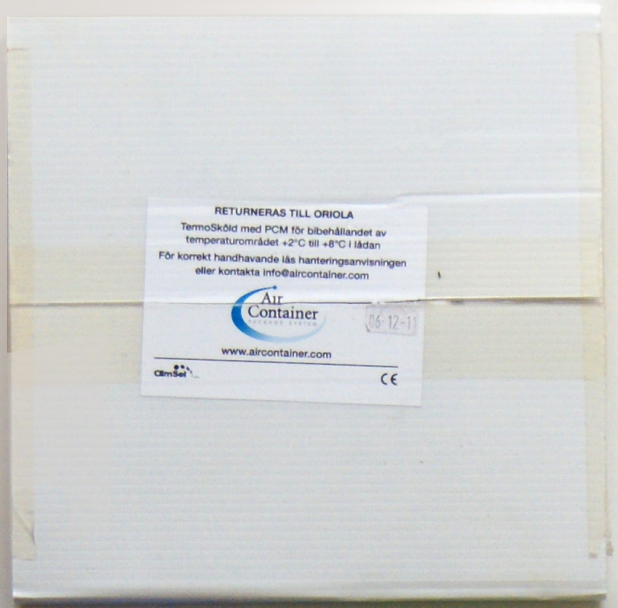
One option of using a more active cooling system is by using a compressor and a heat exchanger. One of the major issues of this application is the increase in weight of the entire system (Palm, B.). The system also needs an electric plug, which implies the availability of a wall socket. Another possibility is to use batteries and adaptors to these. The advantage then becomes the increased portability and flexibility. However, batteries have a set battery life before it needs to be replaced or recharged (Palm, B.). Thermoelectric solutions are more commonly used in professional contexts such as by medical transports, catering, fishermen etc. and is thereby often larger in size and more expensive.

Insulation

After consulting professor Björn Palm it was found that insulators in this type of application are preferably vacuum or insulators with thermal conductivity close to the

FIGURE 3. Selection of different cooling media.

COOLING MEDIA



one of air, 0.02-0.04 W/(mK). Good insulators also reduce the total volume of the container (Williams and Bishara, 2010), which is an important aspect for this application. However, good insulators generally costs more (Williams and Bishara, 2010), wherefore the following insulators fulfil both the requirement of thermal conductivity and factors such as price and CO_2 footprint:

- Cellular Plastics - 0.029-0.039 W/(mK)
- Mineral Wool - 0.030-0.040 W/(mK)

As the insulation was regarded as highly important for the application of interest and that the competitor analysis did not clarify the different kind of insulations used today, the following sections describe each of the investigated groups of insulations more thoroughly in order to enable a suitable selection in the latter part of the concept development.

Cellular Plastics

According to the interviewed Ronnie Petersson, expert at DS Smith Packaging in cellular plastic, cellular plastics are a group of foam polymers that were found to be relevant as they have good insulation properties with thermal conductivity ranging from 0.029-0.039 W/(mK) (Petersson, R). The density of the cellular plastic should be kept very low in order to obtain excellent thermal properties; such densities are in the range of 16-35 kg/m^3. Cellular plastics with these densities are for instance Expanded polypropylene, Expanded polyethylene, Expanded polystyrene and Extruded polystyrene foam.

Expanded polyethylene

Expanded polyethylene (EPE) is foam created from low-density polyethylene (LDPE) (Best International Holdings Group Limited, 2012) and is often used in applications such as protective packaging for high-valued or fragile products (DS Smith Packaging, a). The material is also often used as thermal insulating material due to its good insulating properties. Additionally, the material is also lightweight and durable (DS Smith Packaging, a). The material has the thermal conductivity of 0.036-0.038 W/(mK) depending on the chosen density (JSP, a).

Expanded polypropylene

Expanded polypropylene (EPP) is a high quality material with good energy absorption and high strength properties (DS Smith Packaging, b). The EPP is durable, lightweight

and recyclable which make it a versatile material for an array of applications, amongst those are packaging and consumer products (JSP, 2011). The thermal conductivity depends on the density and range between 0.035 and 0.037 W/(mK) for densities of 30 g/l and 50 g/l respectively (JSP, 2013).

Expanded polystyrene

Expanded polystyrene (EPS) is a solid plastic that consists of 90-95% polystyrene and 5-10% gaseous blowing agent, commonly pentane. EPS can be used in several different applications but is most often used as protective packaging of for instance consumer electronic products. The material has excellent thermal insulation properties and is fully recyclable. (DS Smith Packaging, c) The thermal conductivity of the EPS is 0.035 W/(mK) (Saint-Gobain ISOVER AB, a).

Extruded polystyrene foam

The extruded polystyrene foam (XPS) consists of closed cells and has a thermal conductivity between 0.034-0.036 W/(mK). The material is often used as insulator in constructions with low stress (Saint-Gobain ISOVER AB, b).

Mineral Wool

Mineral wool is an excellent insulator as it has thermal conductivity of 0.030-0.040 W/(mK) (Saint-Gobain ISOVER AB, 2008). Mineral wool is made out of rock or slag, stone wool and glass wool respectively, (Saint-Gobain ISOVER AB, 2008) and then combined with a binder in order to make the material into batts (Wilson, 2008). The material is porous, which efficiently traps air and thereby becomes a very good insulator (Saint-Gobain ISOVER AB, 2008).

Vacuum and Vacuum Insulated Panels

In general, the insulator with best thermal conductivity is vacuum (Palm, B.). Vacuum can be used in so-called vacuum insulated panels (VIP). However, the VIPs possess an inevitable gradual loss of vacuum over time and have a high material cost, 147 EUR/m^2. (Binz et al.)

3.2 USER PROFILE

The users of the medical cooler can be classified into the main groups of primary, secondary and side users depending on their interaction with the product and in which purpose it is used (Janhager, 2005). The diversity of the users' characteristics is described in the following sections.

3.2.1 Primary Users

The primary users of the medical cooler are patients who are prescribed with biopharmaceuticals, since these users are the ones who use the product and its elements for its primary purpose (Janhager, 2005). The strongest denominator of the user group is that they all use biopharmaceuticals regularly and have a travelling experience, which requires the possession and usage of a medical cooler.

Target Users

Due to the extensive size of the primary user group, a selection of a target user group was found relevant. The target user group were chosen based upon the group of users, which were the author's first connection to the project, namely users with the chronic diseases Rheumatoid Arthritis (RA), Juvenile Idiopathic Arthritis (JIA) and Multiple Sclerosis (MS). According to Decision Resources (2011), a well-reputed research and advisory firm in pharmaceutical and health care, the most common biopharmaceuticals for treatments of RA and JIA was in 2011 Enbrel (43%) and Humira (42%). These treatments are prescribed to users that have a moderate active disease profile (FASS, 2013a & 2013b). Moreover, Biogen Idec (2011) highlight that one of the most common biopharmaceutical treatments in 2011 for MS was Avonex. Avonex was found to be prescribed to users with a low active disease profile (FASS, 2012). Based on these inputs regarding the disease profile, the target user of the project was defined as a user with low to moderate active disease profile, which thereby can be assumed to have low to moderate disabilities due to their chronic disease.

Biopharmaceuticals

After further investigation of the three biopharmaceuticals, where handling, durability and storage recommendations were compared, see table 1, it was found that the pharmaceutical Enbrel could be stored in an ambient temperature of 25°C for up to 4 weeks, which reduces the need of a medical cooler compared to the other biopharmaceuticals. Enbrel has therefore not been a main focus of the development of the medical cooler.

TABLE 1. Compilation of the three biopharmacueticals of focus and their important properties.

	AVONEX	ENBREL	HUMIRA
Treatment	MS	RA, JIA	RA, JIA
Owner and Manufacturer	Biogen Idec.	Pfizer	AbbVie
Storage Temperature	2-8°C	2-8°C	2-8°C
Durability in 25°C	Up to one week	Up to four weeks	Up to two weeks
Injection	Once/week	Once/week	Once/week
Pen/package	One	Four	Two
Package Dimensions (mm)	25x57x160	65x131x171	34x85x193

(*Sources: FASS (2012, 2013a & 2013b), Johansson M. and Larsson A.*)

Prevalence

The amount of patients in Sweden who are prescribed with these biological substances and thereby also become potential primary users of the medical cooler were in 2012 around 18 000 individuals (Socialstyrelsen, 2013). However, the amount of patients with these chronic diseases in Sweden are about 50 000-100 000 for RA and 17 000-18 000 for MS. The amount of patients with JIA is not clearly defined, yet around 180 children are diagnosed with JIA per year in Sweden (1177 -Medical Care Counselling, 2011 & 2012). Internationally, the prevalence in the US of RA were in 2012 well over 3 million and about 290 000 for MS (Life Science Analytics Inc, 2013).

Demographics

By including these three groups of patients into the target user group, the group consists of a variety of individuals including women, children and men from the ages of 16 and up to senescence. A delimitation set on the target group was their need to have some travelling experience, thereby also be able to travel independently and be responsible for their own medication. All patients of JIA is therefore not included as a primary user but instead a secondary user due to their young ages.

Physical and Cognitive Abilities

As stated previously in the chapter, the target users have low to moderate disabilities due to their chronic disease. Denominators in the users' physical and cognitive abilities

are that patients with RA and JIA may experience reduced muscle strength in their hands and arms as well as experience stiffness in their joints. The disease also affects the body in ways that may make the user experience fatigue. (1177 -Medical Care Counselling, 2011 & 2012) Patients with MS may experience similar symptoms such as muscle stiffness and fatigue, but also reduced balance and ability to walk. (1177 -Medical Care Counselling, 2011) All three chronic diseases may also cause visual difficulties, which may affect the cognitive skills of the patients. (1177 -Medical Care Counselling, 2011 & 2012)

3.2.2 Secondary Users

The secondary users of the medical cooler are users who use the product but not for its primary purpose (Janhager, 2005). Users characterised by this are for instance relatives or travelling companions to the primary user as they are in contact and may interact with the product to some extent during the usage. Another group of secondary users are those who use the product without transporting biopharmaceuticals. The medical cooler may be used as an ordinary cooler for food and drinks at the travel destination, both by the primary user and their travel companions, whom in that case both are secondary users of the product. The owner or their friends and family may of course also use the product as an ordinary cooler at any desired location. However, as the cooler is aimed at transporting biopharmaceuticals, it will not be optimised for a secondary use. A group of potential secondary users are the medical representatives that transport biopharmaceuticals to demonstrate and showcase medicines at different hospitals, care centres and medical congresses.

3.2.3 Side Users

The side users are defined as users who are affected by the product in daily life but have not chosen to use the product (Janhager, 2005). Regarding medical coolers, these users may be security personnel at airports, aircraft crew as well as friends and family to the primary user. These users will in some situations be affected by the medical cooler without actually using it for any certain purpose. Situations like that could for instance occur in various travelling scenarios such as the airport security screening.

3.2.4 General User Requirements

In order to elicit user demands as well as to gain an understanding of the potential users of the product, interviews and surveys were performed. The surveys were online based and reached the potential users through being posted at online forums and in online newsletters by organisations such as Unga Reumatiker. The interviews were held during meetings with users, who were contacted with aid from national organisations for persons with rheumatoid arthritis and persons with neurological disabilities. For further details regarding interview and survey questions, see Appendix V. Interview Guide Users and Appendix VI. Survey.

The findings from these user studies indicate that the primary users value the flexibility of the cooler as well as the reliability and cooling capacity. Several users also expressed that today's coolers were regarded as lacking in these aspects. In addition to this, some users stated that today's sponsored cooler bags were lacking in shock resistance and thereby could potentially damage the medication inside. Another interesting factor that users mentioned were the desire to make the cooler more personal and less attention demanding, as today's coolers sometimes was considered to be embarrassing to use due to their sometimes cheap and non-qualitative expression and associations to illness and medical care. It was also found that users experience a need of some kind of feedback from the cooler, as it was found difficult to know whether or not the temperature inside the cooler bag was sufficient during the travel. Interior-wise, the findings indicate that the users value an organised layout, which is easy to interact with and intuitively understand.

Regarding the manner of carrying the cooler, a solid preferred way could not be identified in the user studies as different user's favoured different ways of carrying it. Moreover, when asked upon whether or not the users were willing to pay for their cooler instead of receiving a sponsored cooler bag from the health care, a strong majority of 76% of the participants said they were willing to pay for one.

In order to highlight some of the identified user requirements as well as exemplify the user scenario, two persona were created to illustrate the primary users. These may be found in Appendix VII. Persona.

3.3 USE SCENARIO

The following sections are based upon the findings of the interviews, observations and surveys conducted during the user studies as well as on regulations and requirements concerning travelling with medical coolers containing liquid medicine.

3.3.1 Regulations Affecting Travel

During travel scenarios, the biopharmaceuticals need to be kept in their original packaging (Biogen Idec., 2012). It is also essential that each individual packaging is marked by the local pharmacy if they are to be transported separately (Apoteket, 2013b). The labelling helps the security or customs to verify that the medication is exempt. Another important part of travelling with liquid medications is to inquiry whether or not the country of destination has any specific rules regarding import of medicine. (Apoteket, 2013b)

Regarding travels, the travel scenarios with the most regulations and guidelines are those by air. The use scenario of focus were therefore set to air travels. The regulations are set by each airline and country individually but are guided by guidelines set by the International Air Transport Association (IATA). Transportstyrelsen sets the Swedish guidelines whereas Transport Security Administration (TSA) sets the US guidelines.

One important regulation is that the liquid medicine needs to be professionally packed and labelled to avoid being removed by the security personnel (IATA, 2013). Liquid medicine needs to be transported as carry-on luggage (Transportstyrelsen, 2012), meaning that the cooler can't exceed the restrictions in size nor the weight of a carry-on luggage. These restrictions are controlled by the individual airlines, however the carry-on luggage's maximum size is recommended by IATA (2013) to be 560 x 450 x 250 mm. The amount of medication is restricted to an amount that is reasonably necessary for the sojourn (Transportstyrelsen, 2012). According to TSA (2013), accessories that are required to keep the medicine cooled, such as ice or gel packs are permitted through the screening. However, after consulting SAS Medical Department, it was found that the amount of dry ice allowed to bring on-board SAS flights is restricted to a maximum of 2 kg (SAS Medical Department). The medical cooler is subject for screening and should therefore be screened separately from other belongings (TSA, 2013).

3.3.2 Travelling with Medication

The findings of the online surveys, which 27 potential users from 3 countries responded to, indicate that the average travel frequency per year within the target group is 3-4

travels and that 30% of the participants have travel durations of 14 days or more. Despite these indications of a quite active and travel-experienced group, almost 50% of them stated that they sometime had felt limited when travelling due to their medication.

As the medication is to be taken regularly, the average participant need to bring at least two medicine packs into their medical cooler, also taking into account the occasional addition of spare medication that some participants claimed they wanted to pack. The travel duration in travel time was stated to be more than 6 hours for an entire 60% of the participants and almost 40% stated that they usually travel for 12 hours or more to reach their destination. Regarding the mean of transport, the participants stated travelling by air and car as the primary ones, with 40% and 37% respectively. Concerning travels by air, international departures from Swedish airports have increased with 26% between 2009-2012 (Swedavia, 2013), indicating that long distance travels are becoming more and more common. It is therefore of great importance to prioritise the travelling scenarios by air and solve the problems that 44% of the participants had experienced regarding their medical cooler in air travel scenarios.

Regarding the medical coolers, 57% also stated that they had experienced problems during travel scenarios due to their medical cooler. The medical cooler was found to be primarily sponsored ones (67%) even though some participants had bought their own medical cooler despite owning a sponsored one. Due to the medical coolers, 37% of the participants felt that the medications were transported in an unsafe manner and 1/5 of the participants stated that they had experienced that the medication had been rendered unusable due to travelling. For full statistics and demographics see figure 4 on page 37.

3.3.3 Travel Scenario: Flight from Stockholm to New York

In order to understand a typical use scenario and the issues that may arise during the travel, an exemplified flight scenario has been constructed, which includes the preparing and packing of the cooler, transport to the airport, airport security check, on-board the flight, destination and the homeward journey. The exemplified issues were identified during the user studies. An illustration of the use scenario can be seen in figure 5 on page 39.

Exemplified Scenario

The travel scenario begins with the preparation and packaging of the cooler. In general,

the coolers use generic ice packs as cooling media, meaning they need to be put in the freezer at least 10 hours before the cooler may be packed with medicine. When the cooling media has properly frozen, it may be packed along with the desired amount of medicine into the cooler. Ideally, the packing of the cooler should occur just before departure from home in order to maximise the possible travel duration. The travel duration may seem easy to estimate, however users often travel to the airport from their home either by bus, train, taxi or car, which adds to the total duration of the trip. Furthermore, most users arrive at the airport at least 1.5 hours before the actual departure of the flight in order to have time to check in and go through security. Adding these time durations, several users may easily have started their trip 3-4 hours prior the actual flight departure.

When at the airport, the medicine needs to be carried in the carry-on luggage or as a separate luggage to easily be screened in the security check. At the security check, the cooler must be placed on the conveyor belt. On-board the flight, the cooler need to be stored in the overhead compartments a long with the rest of the carry-on luggage. According to Svenska Resenätverket AB (2013), who manages the website flygresor.se, the flight duration from Stockholm, Sweden (Arlanda) to New York, US (Newark) takes around 12 hours with an intermediate landing and an 1 hour transfer time in Frankfurt, Germany. The total travel duration to reach the destination's airport is thereby around 15-16 hours. However, the travel seldom ends at the airport. The checked-in luggage need to be collected and is then followed by an additional trip to the final destination. At the final destination, the medicine need to be stored in a refrigerator again either in a personal one or in the hotel kitchen's refrigerator.

As one can easily understand by this exemplified travel scenario, the duration the medicine lies within the cooler may very well reach up to 20 hours.

Issues

The identified issues of the use scenario, elicited from interviews, observations and online surveys, were compiled using an affinity diagram to structure the issues according to their origin, see figure 5 on page 39.

Regarding travels by air, the findings from the user studies indicate that a commonly experienced problem with the medical cooler was connected to the cooling capacity and that the specific use scenario demanded longer cooling capacities than those found in today's coolers. The use scenario was commonly affected by factors, which the user could

FIGURE 4. Compiled user study results concerning travel habits.

TRAVEL HABITS

26 % increase in international departures from Swedish airports between 2009-2012*

60 % travel for 6 hours or more **37 %** travel for 12 hours or more

60 % travel for 7 days or more **30 %** travel for 14 days or more

3-4 times/year is the average travel frequency

48 % have felt limited when travelling due to their medication

70 % have travelled with medical coolers

67 % have a sponsored medical cooler

37 % feel that the medication is transported in an unsafe manner

1/5 have experienced that the medication have been rendered unusable due to travelling

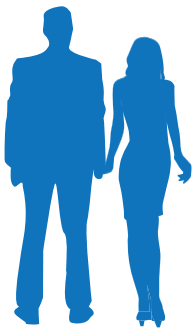
1/4 regard the packaging of the cooler to be complicated

57 % have experienced problems due to the medical coolers

44 % have experienced problems when travelling by air

DEMOGRAPHICS

GENDER



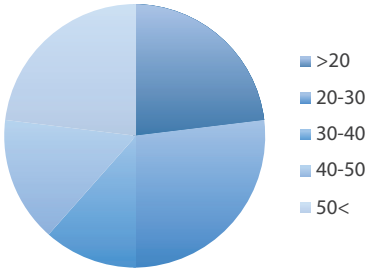
26 % 74 %

NATIONALITY

SWE	22
FIN	1
US	4

No. of Participants 27

AGE



** = Source: Swedavia 2013*

not control, for instance flight delays, security check complications and the availability of refrigerators on the destination.

During the preparing and packing of the cooler, several users regarded the procedure as time consuming and as a non-user friendly experience. Some users also stated that there was not enough space in the cooler for the desired amount of medication. Concerning the travel to the airport, most users stated that they had not experienced any severe issues. However, regarding the airport security most of the users had experienced some sort of issue. These issues often concerned opening of the cooler, which reduces the cooling capacity as the air is replaced by warmer, but also issues of confiscation of the cooling units due to lacking declaration of contents or regulation exceeding amounts.

Overall, the issues concerned the cooling capacity, which was also evident concerning the experienced on-board issues. Some users stated that they solved the cooling of the medicine by putting the cooler in the aircraft's cooled food trolleys. However, after spoken to SAS Medical Department, it is evident that the airlines have restricted capacity to help the users with such requirements. Another frequently mentioned issue when travelling by air was the occurrence of flight delays. However, the origin of that issue was after further study rather connected to the cooling capacity of the cooler and not the actual delays.

At the destination, one of the main issues that users stated was the refrigerator availability on the destination. Some users highlighted that the refrigerators in the hotel room sometimes did not keep the correct temperature and some users stated that they always stored their medication in the hotel kitchen's refrigerators.

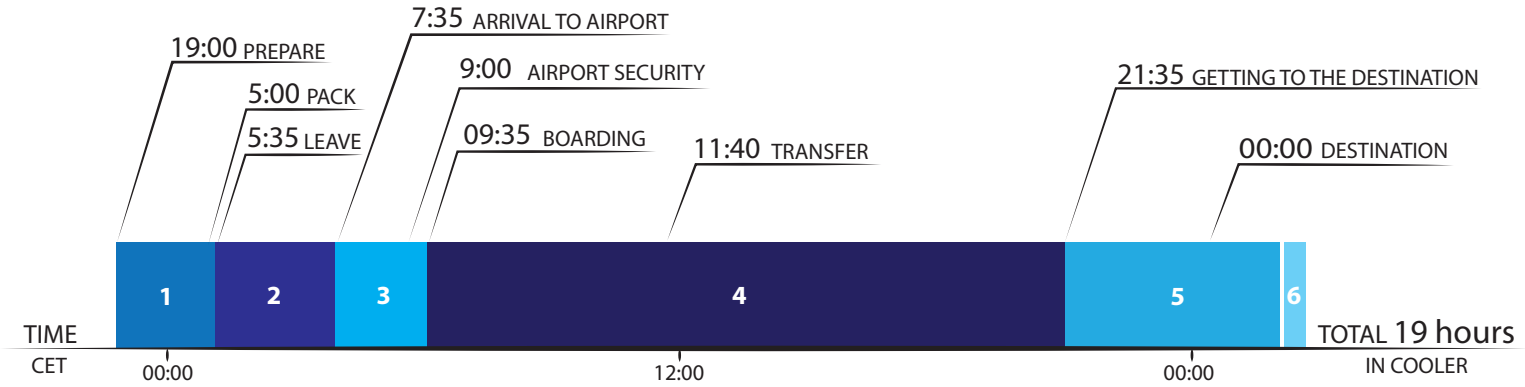
During the homeward journey, the users hardly mentioned any issues although they in some cases said they had spare medication left to be cooled and therefore needed access to a freezer to re-cool the cooling media.

All these issues are connected to the medical cooler and cooler bags of today and the consequences have different severity. However, two of the user's stated that the lacking functionality of the cooler had led to them not being able to bring their medication during travels - a consequence which is clearly severe.

FIGURE 5. Illustration of the exemplified use scenario, the associated issues and quotes.

AIR TRAVELS

TRAVEL FROM STOCKHOLM-NEW YORK



ISSUES

1 PREPARE & PACK

- Cool the cooling units in time
- Time consuming
- Complicated packing procedure
- Medication freezes
- Not properly closed
- Not enough space for medication

2 GETTING TO THE AIRPORT

- Travel distance to airport
- Does not fit into the carry-on luggage

3 AIRPORT SECURITY

- Additional screening of the medical cooler
- Opening of the cooler
- Confiscation of the cooling units

4 ON-BOARD & FLIGHT TRANSFER

- Travel duration
- Re-cooling issues
- Flight delays
- Transfer time duration

5 DESTINATION

- Travel distance from airport
- Ambient temperature
- Refrigerator availability on destination

6 HOMEWARD JOURNEY

- Spare medication needs cooling
- Empty cooler

QUOTES

"The long travel distances combined with the cooling time have led to that I sometimes can't bring my medication."
- Female user, 40-50 yrs

"The airport security often wants to check the medication and cooling units, then I have to open the cooler, which reduces the cooling time."
- Male user, 20-30 yrs

3.4 CARRYING MANNERS

During the competitor analysis and user studies it was found that the models and preferred models of the coolers and cooler bags today were as versatile as the user group. In the use scenario of focus, the medical cooler needs to be transported as a carry-on luggage and need to be handled with ease during a flight scenario. In order to ease the airport security screening, the cooler should preferably not be kept within another carry-on luggage (TSA, 2013). The carrying manners and bag models that were found to be the most appropriate and beneficial with regards to the use scenario and the user demands concerning the desired amount of medication were backpack, duffel, messenger bag and suitcase with wheels. The following sections describe interviewed users' and generic opinions and associations of each of these four models:

Backpacks are in the basic form a cloth sack carried on the back with two straps that go around the shoulders. In many countries backpacks are associated with students for transporting educational material to and from school, this was also the general opinion of the interviewed users. The backpacks are suitably fashionable and useful for carrying heavy loads, due its ergonomic benefits of the shoulder straps that stabilises, divides out and brings the load nearer the user's centre of mass. (Wikipedia, 2013a)

Duffel bags are often used for carrying luggage or sports equipment outdoors. The bag typically has a cylindrical form made of fabric with a drawstring closure at the top. The bag model is often associated to military personnel, sailors or marines. (Wikipedia, 2013b)

Messenger bags are in their simplest form a type of sack, usually made out of fabric, which is carried over the shoulder with a strap that crosses the chest resting the bag on the lower back. The bag model is often associated with an urban fashion accessory. (Wikipedia, 2013c)

Suitcases are in general term a type of luggage, which is mainly used for transporting clothes and other possessions during trips. The bags are made out of metal, plastic or fabric and often include a carrying handle on one side. Many modern suitcases include a built-in telescopic handle and wheels. (Wikipedia, 2013d)

3.5 RELATIONS INFLUENCING THE DESIGN

The studied system consists of the cooler, the thermal technology, the user and the use scenario, which all correlate to each other. One of the main influential factors upon the design is the use scenario, as the cooler needs to take into account the size restrictions and shape of the aircraft's overhead compartment as well as the procedure in the security check and at the airport.

In order to examine the scenario more closely, the cooler bag by Polar Bear Coolers was used to simulate the scenario of putting the cooler into the overhead compartment and thereby gaining an understanding of the crucial aspects and to document these for further development of the final product concept. The scenarios of handling the cooler at the airport and in the security check were also simulated in order to understand important aspects of the design. The simulation sessions were performed as an observation study of a fellow student who were introduced to the use scenario and asked to perform some parts of it.

3.4.1 Handling the Cooler at the Airport and Security

When at the airport the user needs to carry the cooler from the point of check-in to the actual boarding of the aircraft. During that time, the user may need to carry the cooler or putting it down on the floor of the airport while taking a rest at a bench or similar. The actual time of carrying the cooler may vary from travel to travel but may be regarded as relatively short. The cooler therefore need to be easy to carry and be able to stand on its own. The cooler should also for other reasons, such as flexibility during travel to and from the airport, be easy to transport, carry and be put down.

At the security check the cooler need to be put onto the conveyor belt. The cooler should thereby be easy for the user to take on and off the shoulder, back etc. so that it could be easily lifted. The cooling media should also be clearly labelled or marked in a manner that eliminates potential suspicions of its content. During an inspection of the cooler, the security personnel should be able to easily see the medication in order to validate its authenticity, which would minimise the time the cooler needs to be kept open during the security check.

3.4.2 Overhead Compartment of the Aircraft

The regulations from IATA restrict the carry-on luggage to a maximum of 250 mm in one of the dimensions, which is determined based on the height measure of the aircraft's overhead compartment. The simulated scenario indicated that it would be beneficial if the cooler had a stable handle to ease the lifting of the cooler into the compartment as well as removing it after the flight. The size of the cooler bag used in the simulation was regarded as clearly sufficient and a larger cooler could perhaps reduce the user friendliness of the handling as well as the flexibility of the cooler. The goal measures were thereby set to 178 x 305 x 355 mm (Polar Bear Coolers, 2012). The shape of the overhead compartment is slightly rounded in the end, meaning that the cooler could not have sharp edges to that side but rather rounded or curved.

The simulation also indicated that the position of the cooling units could be altered when the cooler are in the compartment from the position they are having when carried in the cooler in the intended way, see figure 6. Instead of cooling the medicine from the top and bottom, the units are alternated to cool the medicine from left and right, which may impact the functionality of the thermal technology of the cooler in a negative manner. This is further investigated in chapter *3.6 Test of Thermal Technology*. The period of time that the cooler is stored in the overhead compartments may very well be the majority of the trip and the cooling capacity while in the compartment should therefore not be compromised.

Another identified factor of importance was that by putting the cooler into the aircraft's overhead compartment, the cooler is exposed to potential impact from the other carry-on luggage or smaller bags that are stored in the same compartment. In order to ensure a secure transport for the medication, the cooler could preferably be made out of shock resistant materials such as plastics or metal, as soft materials such as fabrics may reduce the resistance of shock.

FIGURE 6. The overhead compartments use scenario simulation.


250 mm
560 mm

3.6 TEST OF THERMAL TECHNOLOGY

In order to create a reference for further investigation of the cooling capacity within the cooler, tests of two reference cooler bags were conducted. Following the reference tests, a series of additional tests were conducted in order to explore how manipulations of the cooling media and packaging layout would affect the cooling capacity of the cooler bags. The purpose of the additional tests was to guide the further development of the medical cooler. The layout of each test can be seen in figure 7.

3.6.1 Test Equipment

The equipment used in the test was different cooler bags and cooling media found on the market. The set parameters of the tests were the thermometer and location.

Cooler Bags

The cooler bags used in the tests was the competitor cooler bags for Avonex by Biogen Idec and the medium med cooler by Polar Bear Coolers. These cooler bags were chosen due to their different sizes as well as their different insulation thickness of layered foam. The size of these cooler bags was 115 x 190 x 175 mm with 10 mm insulation and 178 x 305 x 355 mm with 25 mm insulation for Biogen Idec's and Polar Bear Coolers's cooler bag respectively.

Cooling Media

The cooling media used was a selection of ice packs and gels, which was obtained during meetings with packaging companies, health care personnel and pharmaceutical companies as well as bought at the grocery store. The ice packs used in the test were common ice packs bought at the grocery store. These packs contained 400 g ice each. Two different kinds of gels were used, a gel-cuff which was included in the cooler bag by Biogen Idec and gel packs, called Cool Gel by SCA. Both the gel-cuff and the gel packs contained 350 g media each. In addition to this, so-called Techni-Ice was included in the cooler bag by Polar Bear Coolers.

Thermometer

The thermometer used in the test was a common digital thermometer bought at a hardware store, which could show both ambient and an additional temperature. The thermometer was in all tests put in a medicine package in order to measure the temperature which the medicine would have been exposed to.

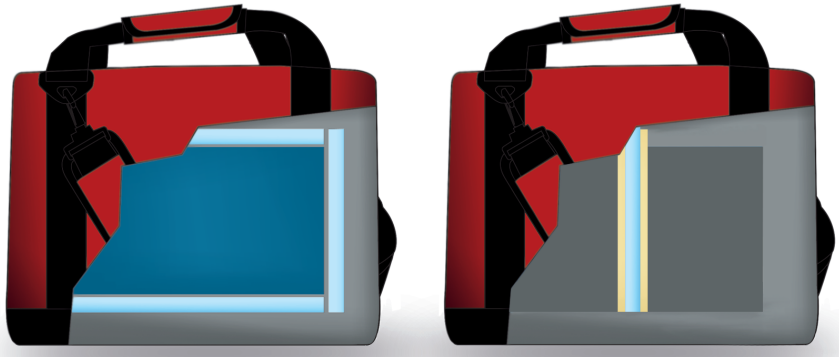
FIGURE 7. Packaging layout of each of the cooling tests.

LAYOUT

TEST A TEST B

TEST 1 TEST 2

TEST 3 TEST 4



TEST 5 TEST 6

COLOUR CODE

ICE GEL FOAM RUBBER MED COMPARTMENT

Context

The location of the tests were in an apartment in Gothenburg with the ambient temperature of 22-23°C during the tests. The cooler bags were not exposed of direct sunlight during the test nor where they moved during the tests.

3.6.2 Reference Tests

Two reference tests were conducted, one of each cooler bag. The Biogen Idec's cooler bag for Avonex was for simplicity referred to as cooler bag A whereas the Polar Bear Coolers's medium med cooler was denoted as cooler bag B. In both reference tests, the cooler bags were packed according to the manufacturer's instructions, as illustrated in figure 7.

Test A

The subject of test A was the cooler bag by Biogen Idec. The results of the test displayed that the cooler kept the desired temperature for 8 hours. Furthermore, the temperature within the cooler bag were the most stable around 4°C. According to the manufacturer, the cooler bag has a guaranteed cooling period of up to 12 hours.

Test B

The cooler bag used in test B was the one from Polar Bear Coolers. The cooler bag was equipped with a plastic box, referred to as med compartment. The included cooling media was two sheets of Techni-Ice. The results indicated that the cooler bag cooled below 8°C for 26 hours, however for 12 of these hours the temperature were below the desired span. The temperature within the cooler bag was the most stable around 1.8°C. The manufacturer guarantee an average temperature of 40°F (~4.4°C) for 12 hours.

3.6.3 Further Tests

The additional tests were conducted in order to explore how the cooling capacity could be manipulated and potentially extended through additional cooling media and layouts.

Test 1

The first test was conducted with cooler bag A. The cooler bag was packed with the included gel-cuff with the alternation of being cooled instead of frozen. The gel-cuff was then wrapped around the medicine package, which contained the thermometer. In addition to this, the cooler bag was packed with 800 g of generic ice packs, 400 g to the

left and right of the gel cuff, see figure 7. The purpose of the alternation was to explore the effect of one cooled media and one frozen media.

The temperature within the cooler bag reached 8°C after 21 hours. However, the coldest measured temperature was 0.2°C, which is outside of the desired interval. The temperature was the most stable around 3°C.

Test 2

The second test was also performed with cooler bag A. This test aimed at exploring the influence of placing a generic ice pack in the top of the cooler bag, see figure 7.

The results from the test indicate that the layout could keep the temperature below 8°C for 23.5 hours. Despite the seemingly pleasant result, the temperature dropped to -11°C and were stable at temperatures below 2°C.

Test 3

The third test was conducted with the cooler bag B. The modification consisted in an addition of ice, in total 1600 g was used, and that the med compartment with the thermometer was wrapped in cooled gel, see figure 7. The purpose of the test was to explore if the cooled gel could insulate the med compartment.

The results of the test showed that the layout kept the desired temperature interval for 27 hours, with a low point at 2.3°C, meaning it never left the interval during the test. The temperature was stable around 2.5°C.

Test 4

The fourth test of the testing series was conducted with cooler bag B and had a similar set up as test 3. However, the purpose of this test was to explore if another protective insulation could improve or decline the cooling time compared to cooled gel. Therefore, the med compartment was wrapped in foam rubber with thickness of <1 cm. Ice packs were then placed on top, in the bottom and on two sides of the med compartment, see figure 7.

The results from the fourth test showed that the layout within the cooler could keep the temperature below 8°C for 29.5 hours. The minimum value noted during the test was 1.5°C and the temperature was the most stable at 5.2°C, which it kept for several hours.

Test 5

The fifth test was conducted with the cooler bag B. The med compartment of the cooler bag was wrapped in cooled gel and then surrounded with three sheets of Techni-Ice, see figure 7. The purpose of the test was to explore how the cooling time would be affected by adding a large quantity of ice as well as gel.

The results of the test was that the cooler bag kept a temperature below 8°C for 40 hours. However, the minimum temperature was measured to 0.7°C, which also was the most stable temperature during the test.

Test 6

The sixth and final test of the pre-study was conducted with the cooler bag B. The test's purpose was to explore how placing the ice packs in the middle of the cooler bag and then adding foam rubber to separate the cooling media from the medication affected the cooling time, see figure 7.

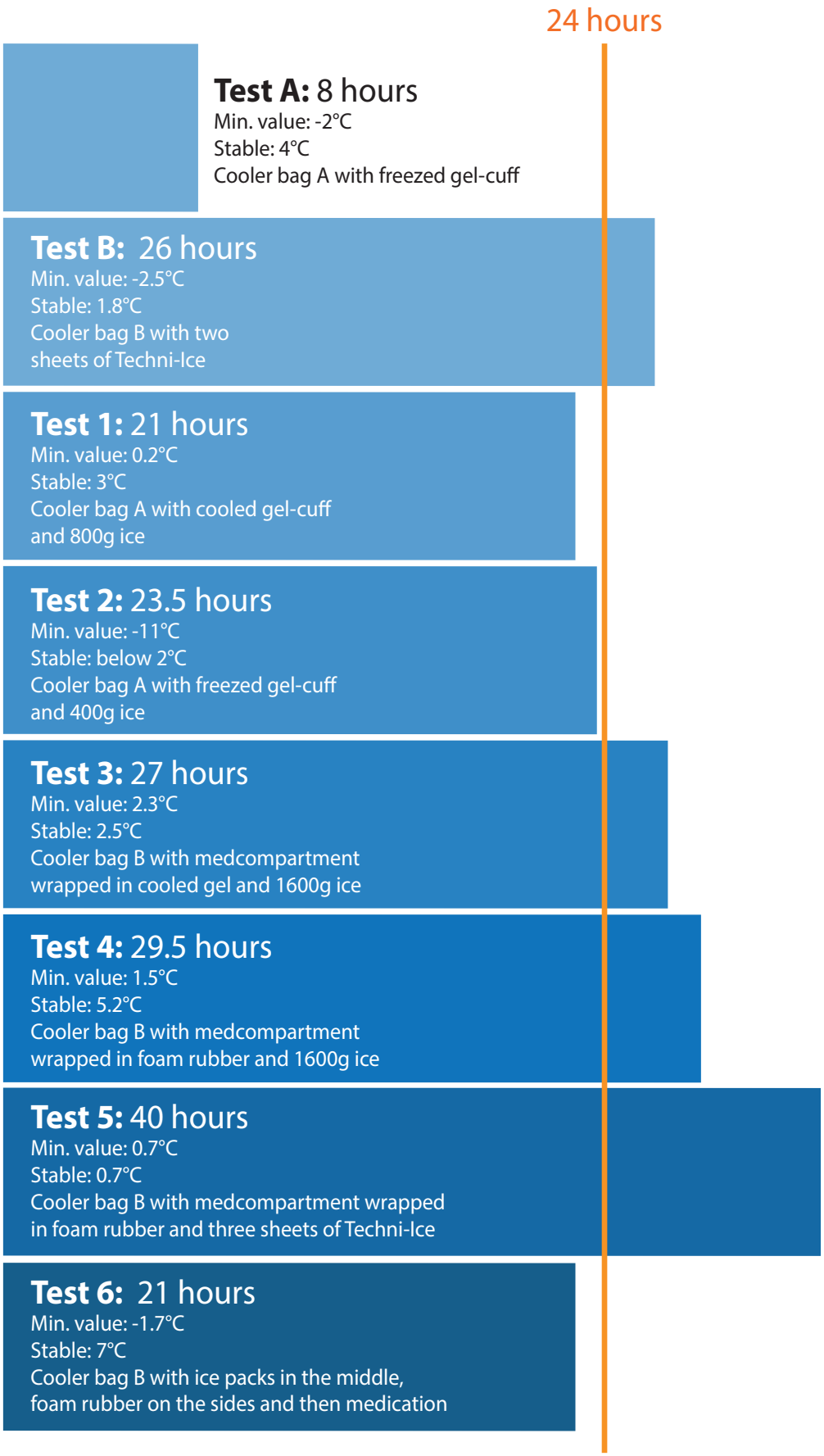
The results showed that the cooler bag kept below the desired temperature for 21 hours with a stable temperature of 6.9-7.2°C for more than 9 hours. The minimum recorded temperature was -1.7°C, which it was for just a short period of time.

3.6.4 Test Summary

The results of the tests, see figure 8, indicate that ice, gel or Techni-Ice as cooling media will very likely maintain the desired temperature of 2-8°C for the set period of 24 hours. The findings from the tests highlight the importance of separating the cooling media from the medication in order to maintain a stable temperature and decrease the risk of freezing them. The results also show that even a small cooler bag may reach sufficient cooling capacity, see test 1 and 2. However, both tests and both reference tests indicated a too great temperature drop in order to be appropriate for the application. The tests also indicated that the more cooling media the longer cooling time, for instance test 3, 4 and 5. However, the more cooling media added, the more the medicine need to be insulated from the cold, see test 5 which dropped outside the desired temperature span and kept below the span during several hours. The addition of a large amount of cooling media will also result in a heavier cooler bag. The aim is therefore to obtain a balance between the amount of cooling media and insulation, a results which is almost obtained in test 6.

FIGURE 8. Compilation of the test results.

RESULTS


24 hours
Test A: 8 hours
Min. value: -2°C
Stable: 4°C
Cooler bag A with freezed gel-cuff
Test B: 26 hours
Min. value: -2.5°C
Stable: 1.8°C
Cooler bag B with two sheets of Techni-Ice
Test 1: 21 hours
Min. value: 0.2°C
Stable: 3°C
Cooler bag A with cooled gel-cuff and 800g ice
Test 2: 23.5 hours
Min. value: -11°C
Stable: below 2°C
Cooler bag A with freezed gel-cuff and 400g ice
Test 3: 27 hours
Min. value: 2.3°C
Stable: 2.5°C
Cooler bag B with medcompartment wrapped in cooled gel and 1600g ice
Test 4: 29.5 hours
Min. value: 1.5°C
Stable: 5.2°C
Cooler bag B with medcompartment wrapped in foam rubber and 1600g ice
Test 5: 40 hours
Min. value: 0.7°C
Stable: 0.7°C
Cooler bag B with medcompartment wrapped in foam rubber and three sheets of Techni-Ice
Test 6: 21 hours
Min. value: -1.7°C
Stable: 7°C
Cooler bag B with ice packs in the middle, foam rubber on the sides and then medication

4 IDEATION

The ideation chapter describes the concept development, from ideas and sketches to the evaluation and selection of a final concept. Initially, the data gathered during the pre-study was translated into design guidelines and requirements that were used as a foundation for the ideation process. It was also of importance to explore and define the product's expression in order to give the product the appropriate personality to enhance the product experience for the primary users. This was followed by iterative cycles of brainstorming sessions to explore, visualise and evaluate different concepts. The outcome of the ideation was a large quantity of early concepts that were evaluated by utilising different analysis and evaluation methods. The main goal of the phase was to select one of these concepts and develop it further into a final concept.

4.1 CONCEPT GUIDELINES

4.1.1 List of Requirements

The ideation process began with an analysis of the collected data from the user studies and literature review by using the method of affinity diagram. The method's outcome was a compiled list of requirements and guidelines for the product concept. The aim with the list was to guide the development and to have a solid base to build the future concept decisions on.

The pre-study indicated that using ice as cooling medium was preferable due to the demands regarding cooling capacity, price, environmental impact and availability on the market. These cooling mediums were also beneficial because due to providing the least volume and weight to the system compared to other cooling media, which correspond with the identified demands of ergonomics and user friendliness.

The competitor analysis indicated that there was a gap in the product segment regarding holding the required temperature for over 12 hours. The pre-study also indicated that the use scenario often implied the medicine to be kept in the cooler for durations up to 19 hours. The combination of these findings, evoked a desire to develop a cooler which could maintain the temperature of 2-8°C for up to 24 hours.

Concerning the amount of medicine to fit into the product, the requirement is based upon the results of the user studies, which indicated that a large quantity of the users travel for a long period of time, 3-4 weeks and that they often desired to bring spare medications. The requirement is also based on the insight that neither of the competitor products were able to transport a large quantity of medicine.

It was also found important to develop a cooler especially designed for transporting medicine as it might improve the poor reliability of the product if they were targeted at one specific market.

The full list of requirements can be found in Appendix VIII. List of Requirements were the requirements' importance also is stated. The following bullet list is an extract from the list of requirements and guidelines:

- Create an intuitive packaging layout and minimise the risk of user errors.
- Easy to use at home and during the travel.
- Easy to handle and bring on-board the aircraft.

- Removable and reusable ice packs.
- Contain water-resistant compartments for ice packs.
- The ice packs should not be able to alternate into a different position that affects the cooling capacity.
- Competitive price level.
- Admit quality and user-friendliness.
- Be recognizable and differentiate from other medical coolers on the market.
- Compact design and space efficient in order to deliver a flexible product.
- Materials of high quality, good functionality, low environmental impact and price worthy.
- Shock and vibration dampening material.
- Temperature resistant material.
- Hold sufficient medication for a stay of 3 weeks (i.e. at least 5 Humira Pen or 5 Avonex Pen inclusive 2 spare medicine packages).
- Dimensions shall fit the original packages of 5 Humira Pen respective 5 Avonex Pen.
- Temperature indication and prediction of remaining cooling time.
- Possess a form factor that corresponds with carry-on luggage.

4.1.2 Concept Features

In order to ease the concept development, the product requirements and guidelines were condensed into actual design features and expressions that should be applied in the concepts' product design. Both appreciated and less appreciated features and expressions were taken into account to guide the design process as well as to obtain a holistic view of the most important aspects of the product. The following features and expressions were identified as the most and least appreciated in the product design:

Appreciated

- Intuitive packaging layout
- Compartmentalised
- Compact design
- Easy to carry
- Feedback regarding current temperature and remaining cooling time
- Admit reliability, quality and user friendliness
- Express confidence, performance, flexibility and simplicity
- Be caring and encouraging

Less Appreciated

- Cheap expression
- Connotations to illness
- Attentiveness
- Bulky

4.1.3 Inspiration

The following products, see figure 9, were used as inspiration during the ideation phase as they were regarded to possess several features that were regarded as inspirational, desirable and also applicable for the new product. The three main expressions, reliability, flexibility and simplicity, were derived from the list of requirements presented previously in chapter *4.1 Concept Guidelines.*

Reliability

The Cactus Insulin Management by Entwurfreich, see number 1 in figure 9, was selected as inspiration for the expression reliability. The product concept was developed to support diabetics by providing relief in everyday life, reliable long-term-recording and integration into the modern lifestyle. The design was regarded as inspirational due to its seamless and simple design as well as being easy to handle with flexibility in an everyday situation. According to the manufacturer, the product can be seen as a daily companion for diabetics, which creates more of a lifestyle than a necessity (Entwurfreich, 2013).

Flexibility

The Adidas by Stella McCartney Media Pouch, seen as number 2 in figure 9, was regarded to expresses a modern and flexible design language, which was found highly suitable for the desired application. The portable and flexible design of the pouch indicates an easy and close by storage of ones possessions (Adidas, 2012). The choice of materials on the pouch also expressed protection with style, a characteristics that were found highly relevant for the medical cooler.

Simplicity

The lamp packaging by Audrey Blouin, seen as number 3 in figure 9, was regarded as a good example of a simple and compact packaging design. Using a small sheet of corrugated cardboard the fluorescent bulb was considered effectively protected (IGreenSpot, 2013). The packaging was found to be inspirational as it solves the problem with refinement and simplicity. The design express honesty and innovation in an appealing manner.

FIGURE 9. Inspiration board.

1

2

3

4.2 DEVELOPING CONCEPTS

The concept development proceeded with ideation sessions of brainstorming and other ideation triggers. Initially, the focus of the sessions were to optimise the thermal technology and packaging layout, which then lead on to the exploration of how to apply the ideas of thermal technology and layout into different medical cooler models. The ideation sessions were also focused on exploring how the design could fulfil the set requirements and guidelines. The early concepts developed were analysed and evaluated in order to select and define a final concept.

4.2.1 Early Concepts

The findings of the tests of thermal technology from the pre-study, chapter *3.6 Test of Thermal Technology*, indicate that the cooling time was improved by increasing the amount of cooling media, by placing them more efficiently and by adding additional insulation between the medication and the cooling media to protect it from temperature drops below the required 2°C.

Based on the test results, three concept layouts were developed with different orientation and amount of ice packs, see figure 10. The first layout was based upon encapsulating the medicine and by cooling it from four directions. The second layout was created based on the test that showed improved cooling time by cooling the medicine from two directions and placing the medicine in the centre. The third and final layout concept was based upon creating an even spread of the cooling and thereby to place the ice in the middle of the cooler and the medicine on two sides of the cooling unit.

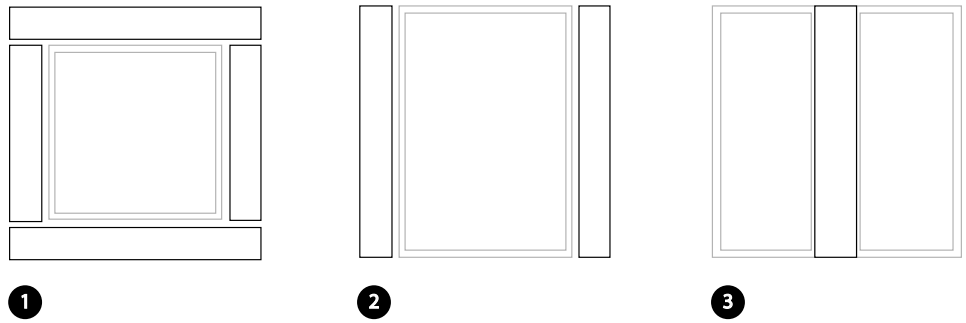


FIGURE 10. Illustration of the three concepts of packaging layout.

FIGURE 11. Sketches of early concepts of the medical cooler and carrying manners.


RUBBER LIST
TELESCOPIC HANDLE
CLASP
ZIP
LOGO
MED
ICE
PRESCRIPTION CASE
Safe compartment
is
EARS
is
is

These three layouts were applied in the sketching of cooler and cooler bag concepts, even though some minor modifications were applied on the concepts in order to create an interesting design and form factor.

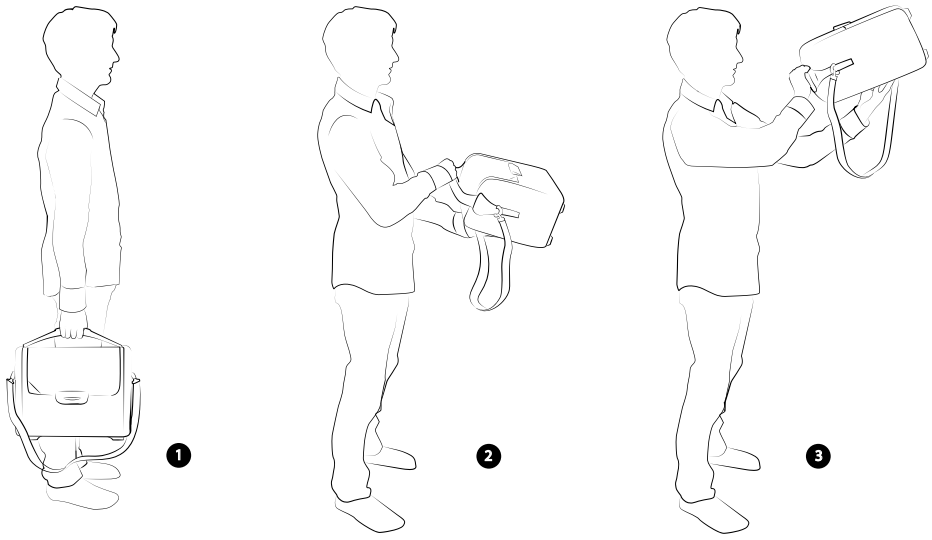
As the pre-study indicated that the carrying manner of backpack, duffel bag, messenger bag and suitcase all were of interest for the application and neither of them were regarded as especially preferable by the primary users, all four models were included in the ideation and concept development. However, the user's physical and cognitive disabilities such as reduced muscle strength, muscle stiffness and/or fatigue were also taken into account when developing ideas as they potentially could influence the choice of model. One of the main focuses and challenges when developing the ideas was to find a flexible and easy way for the user to bring the medical cooler during the travel, without having to feel strained or limited by their disabilities. Based on this, four groups of concepts were developed and visualised through sketches, see figure 11 on the previous page. Each of the groups represents one of the models of interest; backpack, duffel bag, messenger bag and suitcase with wheels.

4.2.2 Evaluation of Early Concepts

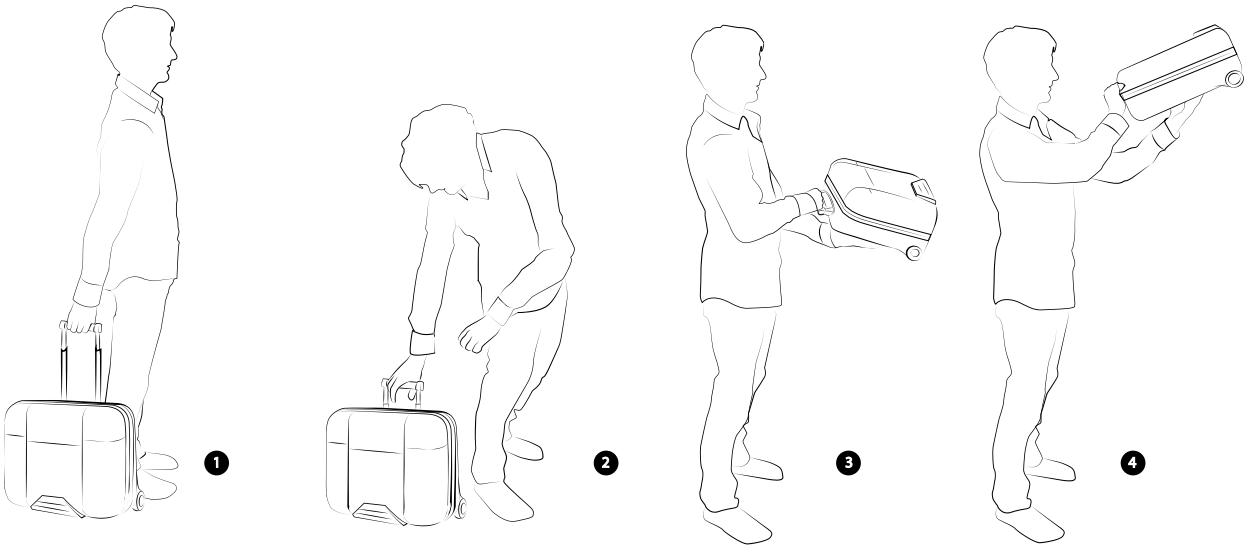
In order to evaluate the four different concepts of medical coolers, both a SWOT analysis and a user scenario analysis were conducted in order to complement each other's results. For the SWOT analysis, the strengths, weaknesses, opportunities and threats of each concept were listed and then compared with the other concepts in order to select the most beneficial concept that both fulfilled the demands regarding aesthetics, economics, ergonomics, functionality and usability and had the most preferable profile in the SWOT analysis. For detailed data, see Appendix IX. SWOT.

The use scenario simulation, see figure 12, aimed at highlighting preferable and non-preferable features of the concepts, both regarding size and form but also the actions where the users' physical status was affected. The simulation also highlighted which of the layout concepts that would be beneficial to apply in the medical cooler. The simulated scenario had identical procedure as the ones performed in chapter *3.5 Relations Influencing the Design*, as that scenario was found to influence the design of the medical cooler.

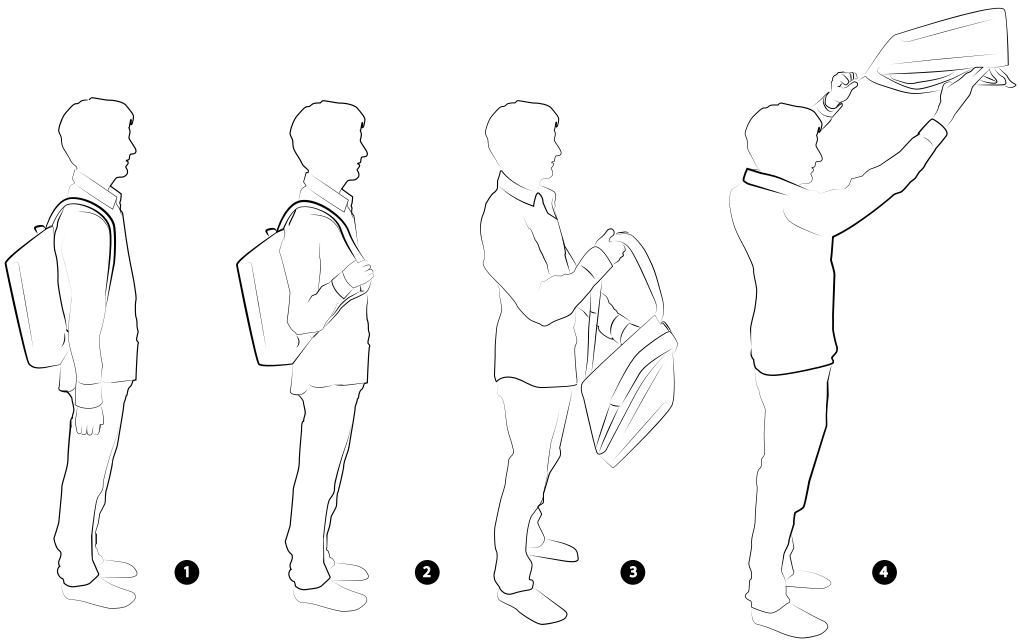
FIGURE 12. Use scenario with different types of carrying manner.



MESSENGER BAG



SUITCASE WITH WHEELS



BACKPACK / DUFFEL

Packaging Layout

One of the main influencing factors when selecting the packaging layout was how the ice packs behaved in the use scenario regarding the possible alternation of position, which could potentially affect the cooling capacity. The use scenario simulations showed that the packaging layouts changed position when the cooler was being handled on-board the aircraft. However, the packaging layout with the ice packs in the centre of the cooler was considered as preferable since the placement enabled the least alternation of the position of the cooling media.

Suitcase with Wheels

The SWOT analysis showed that the suitcase with wheels mainly possessed weaknesses and threats regarding the size and weight due to the additional features such as telescopic handle and wheel construction, which resulted in a needlessly larger and more expensive product. Even though the suitcase with wheels may be regarded as optimal for getting around at an airport it had weaknesses concerning handling on-board the aircraft, for instance lifting it into the overhead compartment.

The user scenario simulation also indicated that the suitcase with wheels would be more complicated to handle during the on-board scenario due to its size, form and also the additional weight of the cooler. As stated in the previous paragraph, the suitcase with wheels would be beneficial when getting around the airport. Another important negative aspect of the suitcase with wheels was that the probability that the user had another suitcase with wheels on the trip was regarded as great since the trips of focus have around 3 weeks duration. However, the reduced user friendliness, economic aspects and bulkiness on-board the flight eliminated the suitcase concept from further development.

Duffel Bag

The duffel bag was considered to share the same potential threats as the suitcase with wheels of becoming too bulky for the application, which was previously identified as a less appreciated feature of the medical cooler. The strengths were mainly due to its versatile carrying manners that on the other hand may have the potential threat of poor ergonomics in some of its carrying ways. Regarding the user scenario simulation, the duffel bag had strong benefits regarding flexibility on-board the flight as it would be easy to remove from the body and lift into the overhead compartment. However, the associations to military situations alongside with the identified threats in the SWOT analysis made the duffel bag inferior to the rest of the remaining concepts.

Backpack

The design of the backpack was considered to be complex, as it for instance would have to be optimised ergonomically, which result in a more complicated and expensive manufacturing processes. The main strengths and opportunities were the ergonomic aspects and practical carrying manner. The backpack was also found beneficial during the on-board scenario, as it would be easy to lift the cooler and to transport it through the narrow aisle inside the aircraft. However, one identified potential weakness of the model would be the reduced anonymity as well as the risk of being associated with ridiculousness or children going to school. Another potential disadvantage with the backpack could be the choice of materials since a soft cooler would have reduced impact and water resistance. A hard cooler would on the other hand possess the potential threat of looking like a shell on the back of the user, which would enhance the silliness and could cause embarrassment. Thus, even though the backpack had no severe disadvantages, the carrying manner was regarded to have too strong associations with childishness to become a successful product in the field of medical coolers.

Messenger Bag

The analysis showed that the messenger bag had an upper hand due to its compact design, which correspond to the design goals of being easy to carry. The shoulder strap allow messenger bags to be easily swung around the shoulder, which enables a flexible carrying way. The messenger bag was considered to give a fashionable but discrete look, which may appeal to a large user spectrum. Another advantage with the messenger bag was found to be the flexible choice of materials, as it could possess both a soft and a hard surface without influencing the overall experience for the user. The potential weaknesses and threats were limited in amount yet of importance to consider as one major threat could be the risk of becoming an ordinary cooler bag. The SWOT analysis and the user scenario simulation showed that the messenger bag was one of the most beneficial models regarding carrying manner, aesthetics and economics. The user scenario indicated that the messenger bag was easy to handle on-board the aircraft due to the ease of removing it from the body, lifting it up and placing it in the overhead compartment. Even though the backpack was considered to be more ergonomic to carry, the issue with heavy weight was not regarded as any major concern for the application. The studied use scenario indicated that the duration of carrying the cooler was limited and it was therefore of higher priority to keep the cooler's design simple without excess. The total analysis of the messenger bag indicate that the model would be superior the other models and was thereby selected as the final concept model.

4.3 DEFINING THE CONCEPT

With the packaging layout and the cooler model selected, the concept development was proceeded with further and elaborate sketching to define the features of the medical cooler in order to create a solid design concept. Specific features such as different ways of providing feedback, thermometer alternatives, lock and handle was of high priority during the later ideation sessions. The further exploration of a cooler in the model of a messenger bag with the cooling media in the middle of the cooler resulted in a concept definition, which are described in the following sections. Illustrations of the concept can be seen in figure 13.

4.3.1 Exterior

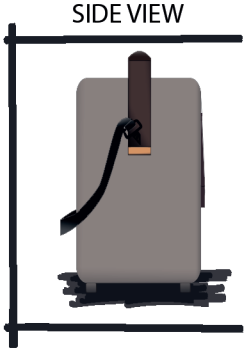
The exterior of the cooler was defined as consisting of both fabric and plastics in order to soften the side of the cooler, which would be closest to the user when carrying it. The plastic sides of the cooler were aimed at possessing impact resistant qualities as well as providing a reliable expression. The interior construction was also based on these plastic components, which would then be reflected both exterior wise and interior wise. The selected colour scheme of the medical cooler was based on nuances of soft colours with the addition of a sharper accent colour. The form factor of the concept was selected to be rounded, both from an ergonomic perspective but also in order to make the cooler volume efficient and conform to the form restrictions from the overhead compartment on-board the aircraft. The front exterior surface of the cooler was accessorised with a logotype of the cooler in order to provide more character and personality to the product.

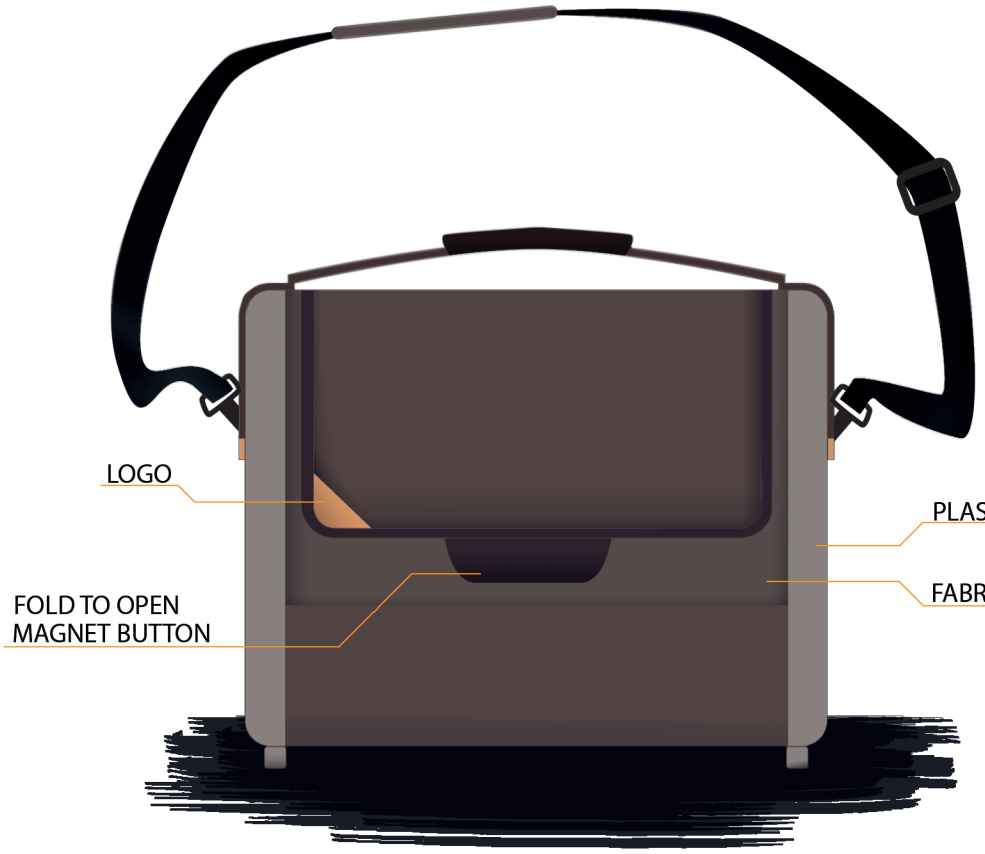
4.3.2 Interior

The interior of the cooler was divided into three compartments, two medical compartments on each side of the third compartment, which was allocated to the ice packs, see figure 13. The medical compartments were dimensioned to hold two packages of Humira or three packages Avonex each, hence a base size of 41 x 180 mm. The size of the medical compartments therefore enabled a total amount of eight and six injection pens of Humira and Avonex respectively. The ice compartment was designed to hold two ice packs with the size of 200 x 88 x 40 mm each. An insulating wall was added between the ice compartment and the medical compartments in order to protect the medication from temperature drops below the required 2°C.

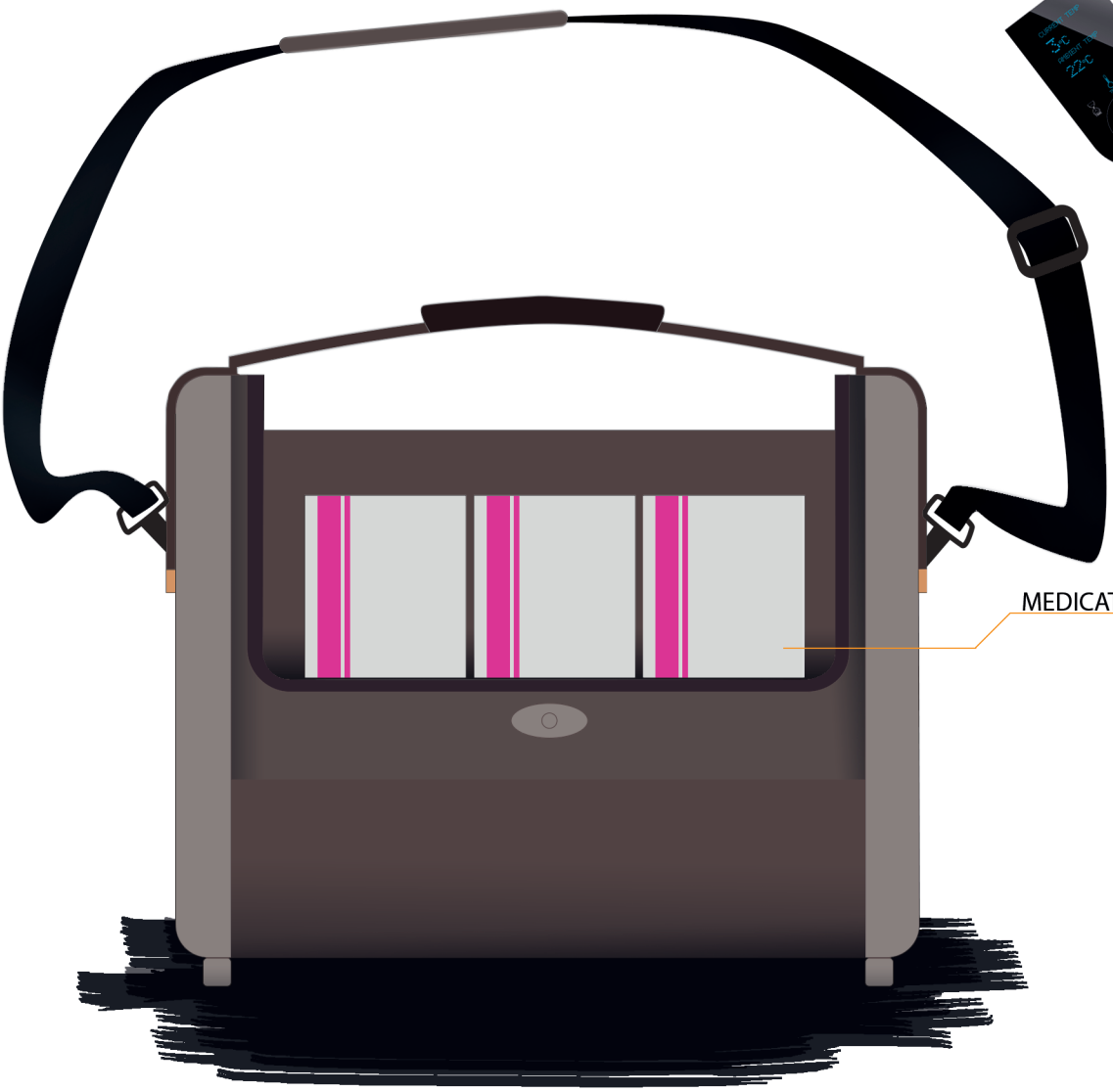
FIGURE 13. Exterior and interior design of the final concept.

SIDE VIEW




LOGO
PLASTIC
FABRIC
FOLD TO OPEN
MAGNET BUTTON


GADGET


MEDICATION

4.3.3 Features

The following sections aim at describing the features of the final concept, such as the lock, handle, shoulder strap and gadget.

Lock

The locking mechanism was designed to give the cooler a secure and airtight closure. The lock consisted of both waterproof zippers and a magnet closing at the front of the cooler. The lock was integrated with the design, easy to grip and manoeuvre and possessed a double-locked protection to prevent it from unlocking itself during the handling and travel.

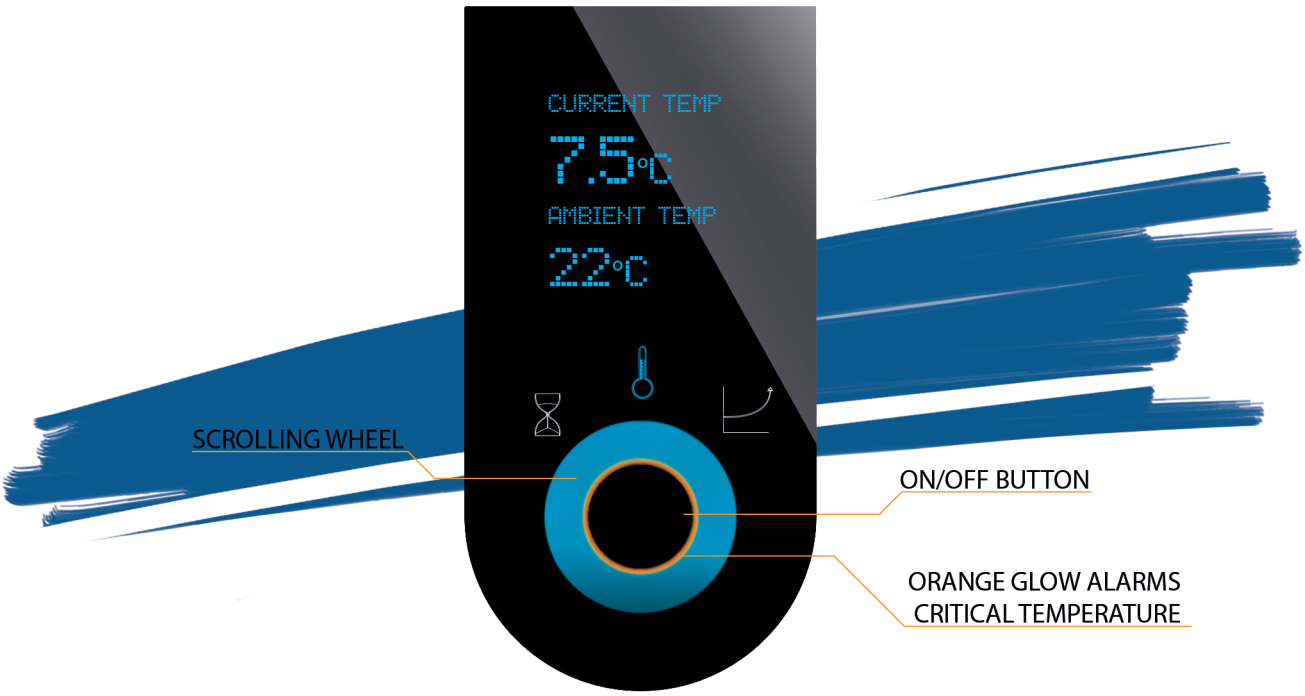
Handle and Shoulder Strap

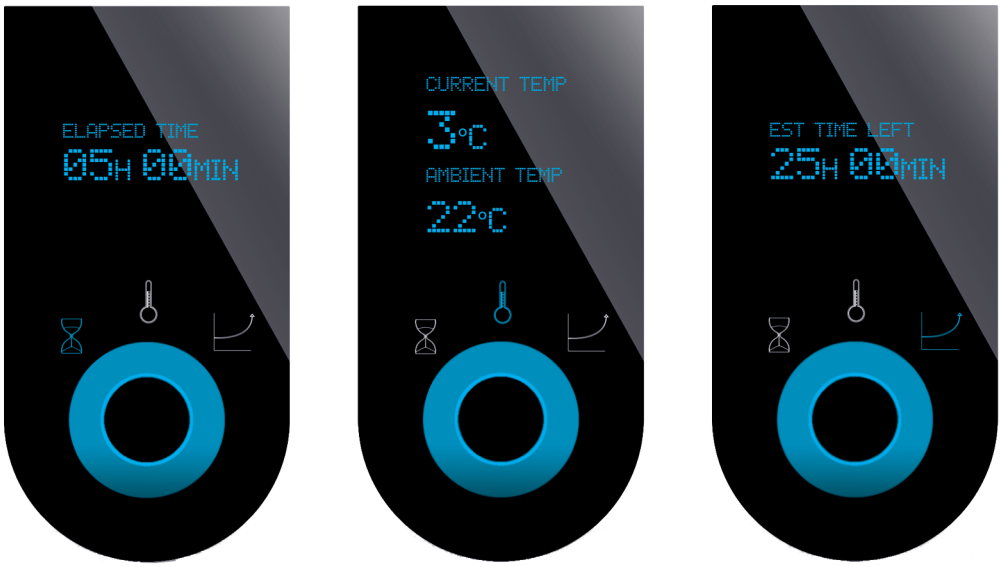
The design of the handle was optimised from an ergonomic perspective by taking the 5th percentile women and 95th percentile men into account during the design and construction. The shoulder strap was designed to be adjustable in order to suit the versatile user group.

Gadget

An additional gadget, which could provide the user with feedback regarding current temperature, ambient temperature, elapsed time, remaining cooling time emerged through the ideation sessions, see figure 14. The size of the gadget was kept small and the gadget was designed as a separate device in order to be able to detach the device from the shoulder strap with a clip. The gadget also possessed an alarm function in order to alert the user when the temperature within the cooler reached a critical level. The gadget was primarily icon based as to fit a large spectrum of users, both domestic and international.

FIGURE 14. Concept of thermometer gadget.





FEATURES

RECORDS ELAPSED TIME | DISPLAYS CURRENT TEMPERATURES | ESTIMATES REMAINING TIME

4.4 FULFILMENT OF REQUIREMENTS

The defined final concept was aimed at fulfilling the set requirements and guidelines listed in the list of requirements. The following sections aim at declaring which requirements that has been fulfilled and those that may be fulfilled to a greater extent in an iterative step of refinements.

4.4.1 Fulfilled Requirements

A majority of the listed requirements and guidelines may be seen as fulfilled, see figure 15, when checking the concept against the list of requirements and guidelines. There are however some requirements and guidelines that are possible to fulfil to an higher degree and some that have not been verified.

Possible Refinements

The requirements and guidelines may be regarded as possible areas of the defined concept where the fulfilment of them may be questionable and where it might be room for further refinements.

- Removable medical compartment.
- Be able to re-cool or refill the cooling during the travel.
- Be water resistant.
- Be impact resistant.
- Be caring, portable and encouraging.
- Stable to put on the ground or table.

Unverified Requirements

The following requirements were not able to determine whether or not they are fulfilled or to which extent they are fulfilled by checking the defined concept against the list of requirements. These verifications will be performed during the evaluation of the final design.

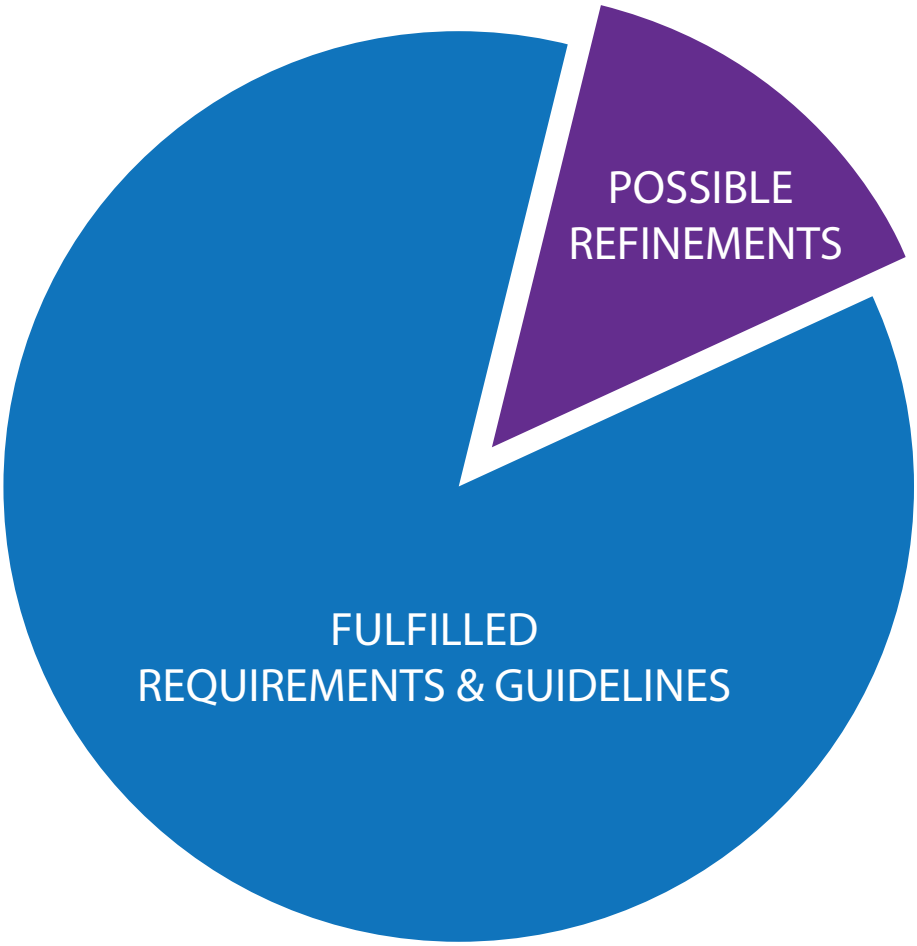
- Hold temperature sensitive medicines.
- Deliver 2-8°C.
- Maintain required temperature for 24 hours.
- Competitive price level.
- Light weight.

FIGURE 15. Graphical overview of the final concept's fulfilment of requirements.

OVERVIEW

Removable medical compartment.
Be able to re-cool or refill the cooling during the travel.
Be water resistant.
Be impact resistant.

Be caring, portable and encouraging.
Stable to put on the ground or table.



UNVERIFIED REQUIREMENTS

Hold temperature sensitive medicines.
Deliver 2-8°C.
Maintain required temperature for 24 hours.
Competitive price level.
Light weight.

Maximum size according to regulations of carry-on luggage.
Be able to carry at least 5 doses of medicine.
Cooling technique should meet the regulations for airport security and airlines.
Compartmentalised.
Removable cooling units.
Cooling units that are designed to fit commercial freezers.
Easy to access the different compartments.
Intuitive packaging solution.
Easy to transport.
Designed for the 5th and 95th percentile women and men respectively.
Easy to open and close.
Volume effective.
Food grade plastics.

Admit reliability, quality, simplicity and user friendliness.
Express confidence, performance and flexibility.
Overall neutral colours
Medicine should be visible when cooler is open.
Thermometer.
Indication of remaining cooling time.
Declaration of cooling units' substances.

5 FINAL DESIGN

The final design chapter describes the Final design & visualisation phase, which began with a refinement process of the selected final concept from the ideation phase. The refined concept was then transformed into CAD models in order to visualise and to further refine the final design concept. Furthermore, the chapter presents each feature of the final design and the underlying reasons for the design choices, aspects concerning the materials and the concept's manufacturing process. Lastly the chapter highlights the benefits with the final concept from different perspectives.

5.1 REFINEMENT OF THE FINAL CONCEPT

As a natural step in translating the final concept from sketches to CAD models, the concept defined as final in the ideation phase went through an iterative refinement process. Even though the concept was refined in several ways, the overall expression and design of the concept were kept untouched.

The material selection of the final concept was further reviewed and the conclusions lead to the implementation of plastics instead of incorporating fabrics into the design. The addition of plastics was based upon the potential threat of creating a cooler with unconventional appearance and use of materials. The dimensions of the cooler also enhanced the change into using solitary plastics, as it would have created too much action on a small area with several texture and material variations.

The change in materials also lead to the development of a new locking mechanism as the one defined for the concept was adapted to the usage of fabric. The refined locking mechanism has a double-safety by incorporating more steps in order to open the cooler. The locking mechanism included two devices, which run on a rail and need to be put together in the middle of the cooler to be able to open it.

The handle was also subject to refinements. Instead of being placed on the body of the cooler, the handle was placed on one of the lids in order to more easily open and close the cooler as well as handling the ice pack, which are to be placed in the middle of the cooler and which compartment would have been partly blocked if the handle was placed as in the final concept.

Regarding the form factor of the design, the curvature was increased in order to enhance the comfort while carrying the cooler. Due to the change of materials from soft shell to hard shell it was necessary to increase the curvature to keep a soft shape against the users' bodies while carrying the cooler. Furthermore, the choice of colour was refined into a more casual and clean concept. The colours that were defined during the ideation phase also contributed to a more professional and industrial appearance than desired and were therefore put under review.

The refinements lead to the definition of a final design concept.

5.2 AWAY

The final design concept *Away* features a reliable medical cooler specifically designed for injection pens with biopharmaceutical substances. *Away* is designed so that the target medicine packages fit perfectly into the medical compartments in a neat and structured way, which enhances the usability and experience of the product in several qualities. *Away* has the dimensions 244 x 198 x 298 mm, which facilitates a cooler that is flexible and easy to use. *Away* is equipped with a thermal control gadget, which provides the user with information regarding the temperature status of the cooler.

Away possesses carefully selected materials along with a neat surface finish in order to create a qualitative product, which is durable, reliable, has low environmental impact and an improved cooling capacity. The design language of *Away* is influenced by the use scenarios of travelling by air and therefore conforms to the design of a carry-on luggage that express a modern and personal character by the curved profile and choice of colours. The simple and minimalistic expression of the exterior is counteracted with the more colourful and expressive interior in order to maintain a more anonymous public appearance yet possess a personal and unique expression during the interaction with the cooler. The contrast is achieved by the white and sophisticated exterior in contrast with the friendly, personal yet trendy purple interior. The exterior possesses the purple accent colour in details such as the gadget in order to couple with the interior design. The combination of contrasts, details and the carefully chosen materials enhance the design of *Away* and facilitates a product of high quality and improved user experience.

In order to amplify the personal, unique and qualitative design, *Away* consists of custom made features such as an ice pack with soft handle and transparent shell, an adjustable and comfortable shoulder strap and a gadget of thermal control.

All in all, the design of *Away* creates a product with core ideals such as reliability, flexibility and simplicity. The design improves the overall experience of the product category with focus on the user, cooling capacity and quality.

Away and its featured accessories are presented in figure 16, see the following spread, and are thoroughly described in the following sections.

FIGURE 16 (following page). The final design concept, *Away*.


MEDICINE


14:10
AWAY

5.2.1 Exterior Design

The exterior of *Away* has a symmetric profile with a generous curvature in the top and bottom in order to create a comfortable and sophisticated appearance, see figure 17. The curvature follows the users' body curvatures and thereby enables a comfortable carrying manner without any risk of bumping a sharp edge into the side of the body. The profile of *Away* is adapted to the use scenario of aircraft travelling and thereby conforms to the design of the overhead compartments and is therefore easy to handle during the entire travelling scenario.

The exterior surfaces of the cooler are of high quality in order to create an approachable and reliable design. The colour choices reflects a minimalistic approach to be able to facilitate a more anonymous expression than competitor products, which reduces the risk of becoming an embarrassing and attention demanding product for the user while in use.

The shoulder strap is attached to a domed circled fastening in a rotatable hook. The strap is carefully designed in order to both be able to adjust the strap's length to the versatile user group's anthropometrics and to easily attach the thermometer gadget to the strap. The strap possesses an ergonomically designed pad in order to enhance the comfort while carrying the cooler. On the side of the strap runs a small hemline in which the gadget's cord runs. This reduces the risk of the cord and strap to get entangled.

The handle of *Away* is designed to be a comfortable grip when lifting or carrying the cooler. The dimensions of the handle are conformed to the measurements of the 5th and 95th percentile women and men respectively with a total grip area of 100 mm and height of 57 mm. The placement of the handle in the middle of the top simplifies the handling of the product as the user puts it in the overhead compartments on-board the flight. The handle also simplifies the opening and closing of the lids, as it provides support and stability to the task.

The locking mechanism of *Away* consists of two sealing devices that run on a rail on top of the cooler. The devices need to be put together in order for the lids to be able to open, see figure 17. Along the edges of the lids runs rubber lists, which seals the lids in an airtight manner and thereby reduces the risk of air-leakage from the cooler. In order to create a secure locking mechanism the sealing devices are provided with magnets

FIGURE 17. Exterior design of *Away* and locking procedure.


AWAY


UNLOCK
UNLOCK
LOCK
AWAY

along the sides to hold the devices in a locked position. The task of moving the devices is designed in a manner that decreases the physical demand of the user and thus enables users with reduced physical abilities to manoeuvre the locking mechanism.

5.2.2 Interior Design

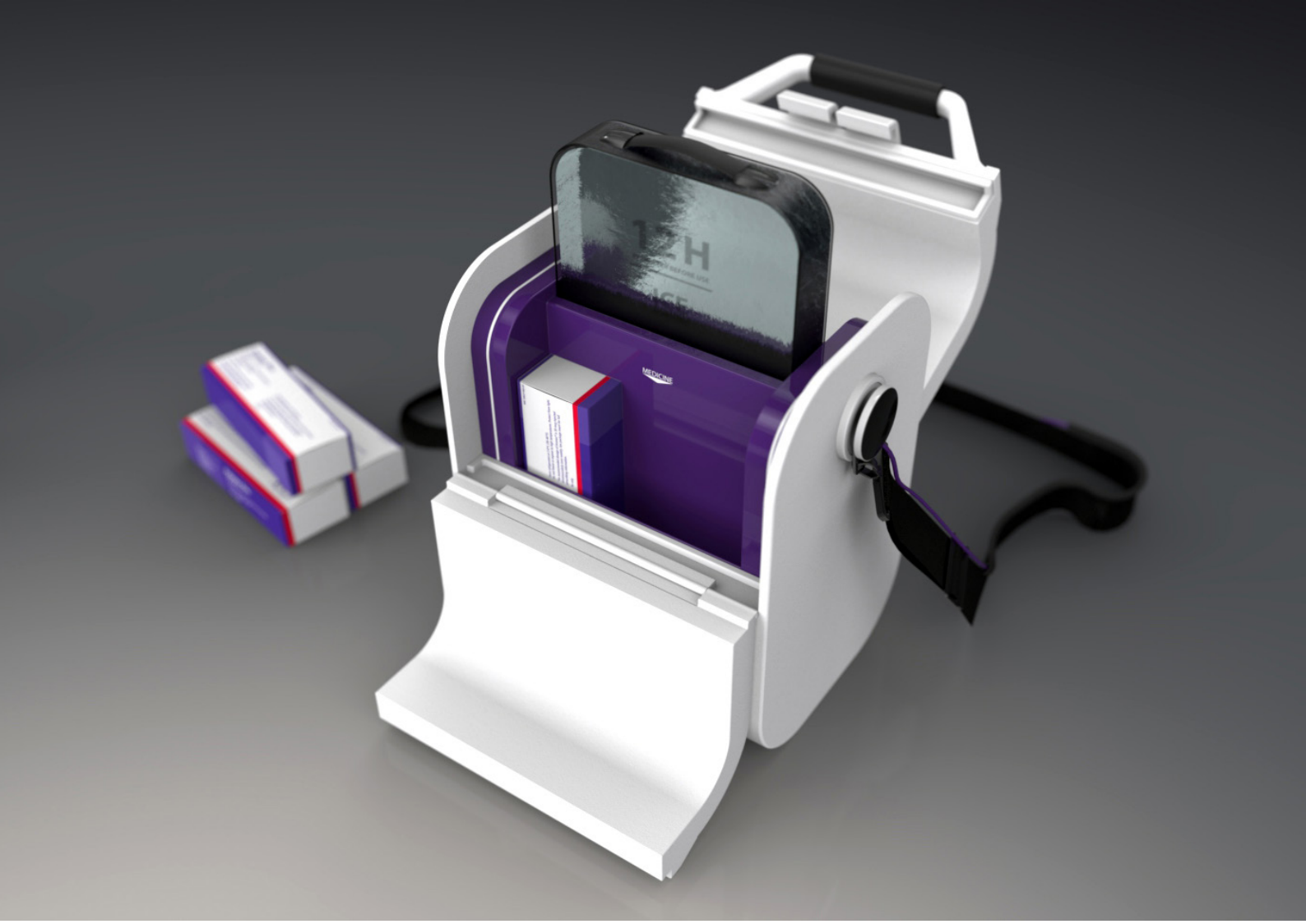
The interior of *Away* consists of three compartments; two are allocated for the medication and one for the ice pack. The compartmentalised design enables a necessary and effective protection between the cooling media and the temperature sensitive biopharmaceuticals to prevent it from temperature drops below 2°C. The structured design also provides honesty and simplicity to the cooler, which makes it look inviting to the user. The ice compartment is placed in the middle of the medical cooler in order to provide an even cooling circulation, see figure 18. The interior layout also conforms to the tests performed of how the layout affected the cooling capacity in the use scenario. The interior layout also enabled a more slim overall width of the cooler, which facilitates a neat expression. The dimensions of the ice compartment are 180 x 40 x 200 mm.

The medical compartments are specially designed for the packages of Humira and Avonex injection pens and are placed on both sides of the ice compartment. The medical compartments enable storage of eight Humira Pens and six Avonex Pens, which gives the users the possibility to travel for at least 3-4 weeks with space for multiple spare medicines. Each compartment has the dimensions 180 x 41 x 200 mm with a front wall height of 105 mm. Even though the compartments are designed for packages of Humira and Avonex, users with other medications may with great probability fit their medications in the given dimensions as they are set with margin.

The medical compartments are designed to provide a sophisticated and organised layout that will enhance the user friendliness of the cooler. The placement of the medical compartments also enables the security personnel at airports to easily get an overview of the content in the cooler and thereby reduce the duration the cooler needs to be open during the screening session.

The colour scheme in the interior provides an interesting contrast to the more minimalistic exterior, see figure 18. The deep purple is sophisticated yet personal and trendy in order to embrace the medicines and deliver more personal appearance. Both the medical compartments and ice compartment are in white font marked with its allocation

FIGURE 18. Interior of *Away* and close-up.


MEDICINE


Autotrax Pen
Autotrax Pen

in order to create a design that is usable without the need of a user manual. A narrow white line runs on the two sides of the interior as to connect with the white exterior surfaces and thereby creates a more solid design concept.

5.2.3 Thermal Control

The concept *Away* is accessorised with a thermal control gadget, which provide information regarding the temperature to the user when desired. The gadget consists of a glass-covered display with a navigation wheel and stand-by button. The navigation wheel is steered by finger touches, which enables an easy usage as well as connecting to the user's mental models regarding similar steering manners of technical products, such as MP3 and other music players.

The design language of the gadget corresponds to the exterior design of *Away* as well as connecting to the colour scheme of both the exterior and interior. The navigation wheel holds the matching deep purple as the interior in order to link the features together without exaggerating the accent colour.

The gadget is programmed to present information only when desired and therefore displays a digital clock in stand-by mode, see figure 19. The user needs to press the stand-by button in order to activate the display and to enter the menu of functions. The gadget has three functions; to display elapsed time, current and ambient temperature and estimated remaining time. The three functions are represented by symbols in order to keep the gadget universal and usability friendly. The gadget also consists of a warning system, which alarms when the temperature inside the cooler reaches a critical level, see figure 18. The purpose of the alarm is to inform the user that the medicines soon need to be re-cooled or put in a refrigerator. The alarm is entirely visual and consists of a light diode, which light up as the temperature reaches critical levels. The display also indicates that the temperature is critical by enlarging the information. The reason of being solely visual is to reduce the stress and attentiveness of a beeping alarm and the potential suspiciousness created by vibrating objects in the use scenario of airports and on-board aircrafts. By being visual, the alarm's significance is reduced which is not negative in this scenario as the user will have time to act upon the alarm before the medicines risk to be damaged by the increased temperature.

The gadget is easily removable from the strap by a clip on the backside. However, to

FIGURE 19. Gadget close-up, interaction and alarm function.


AWAY


CURRENT TEMP
3°C
AMBIENT TEMP
22°C


AWAY
14:10

be able to present information without having to use wireless communication, which in some cases is banned in aircraft environments, the gadget is connected to a cord that runs along the shoulder strap and into the cooler. The gadget is thereby semi-removable, which reduces the risk of losing the gadget during for instance a hectic flight transfer.

5.2.4 Ice Pack

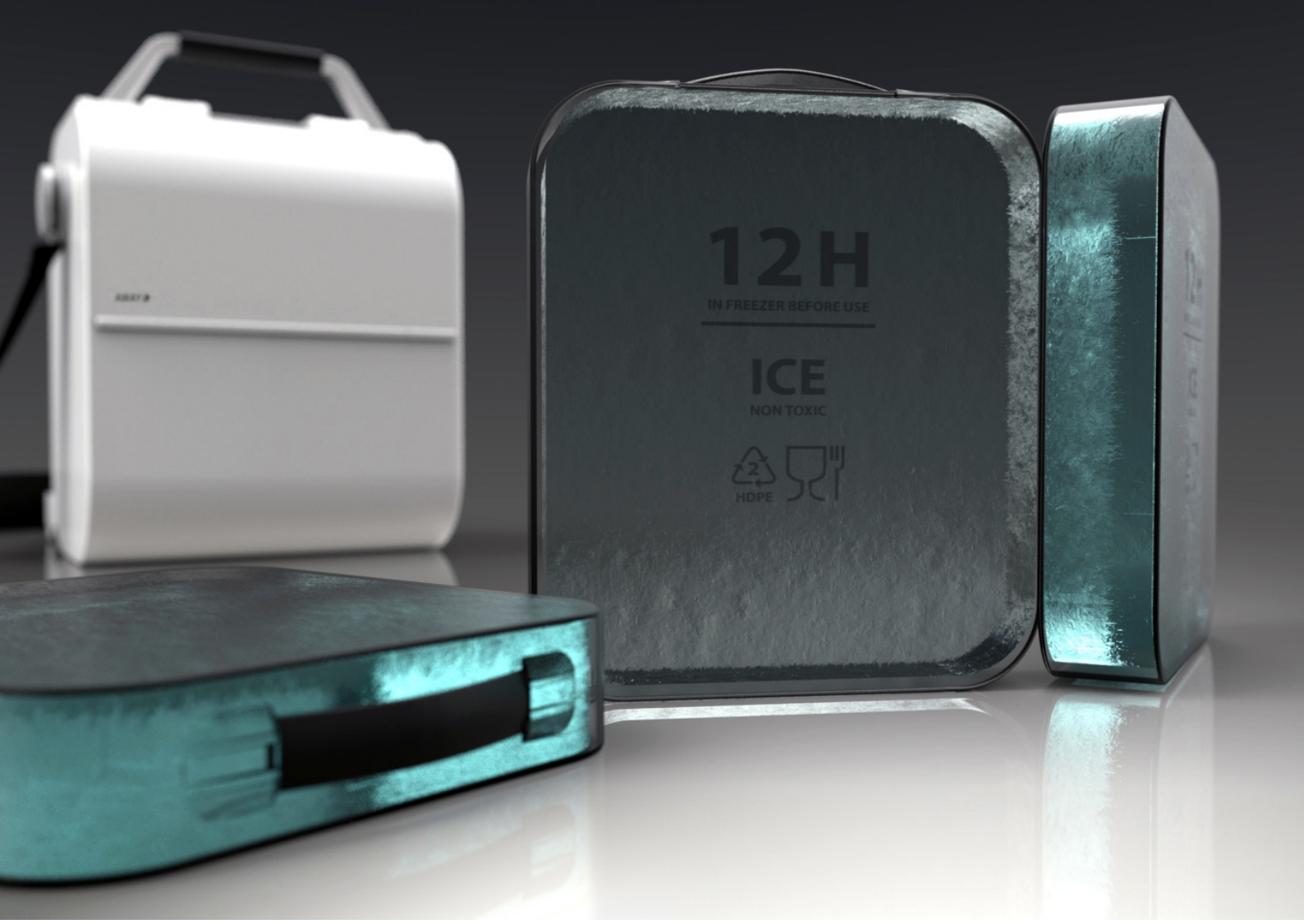
The final design concept *Away* features one larger ice pack with thoroughly balanced volume in order to prolong the cooling capacity yet not interfere with the usability or functionality of the medical cooler. The ice pack is supplied with a soft handle in order to more easily and comfortably interact with it while frozen. The usage of a handle instead of other aids supports a pleasant product experience and provides a more qualitative character to the final design concept, see figure 20. The form factor of the ice pack is designed to relate to the curvatures of *Away*'s exterior and overall design language.

The ice pack possesses a content declaration on the surface of the plastic in order to ease the security screening. The ice pack is also marked with the recommended duration it should be kept in the freezer to properly freeze the content. The plastic coverage of the ice is hard, transparent plastic, which enables the user to view the content and thereby estimate the level of frozenness if desired during the travel. In order to be able to use the cooling unit in other situations as well as dispose it, the ice pack is made of food grade plastic and marked with its resin identification code.

5.2.5 Colour Customisation

Due to the choice of materials, *Away* can be customised in an array of colours and even textures. The possibility to alter the aesthetic feature of the cooler facilitates the creation of an even more personal cooler with custom made prints etc. During the pre-study it became highly evident that pharmaceutical companies tend to brand their coolers in accordance with their graphical profile of each pharmaceutical. If the concept *Away* were to become a sponsored product, the customisation to each company and pharmaceutical would be very feasible and reasonable. An example of potential colour alternations can be seen in figure 20.

FIGURE 20. Ice pack close-up and potential colour options.


12H
IN FREEZER BEFORE USE
ICE
NON TOXIC
2
HDPE


AWAY
AWAY
AWAY
AWAY

5.3 USAGE DESIGN

The usage design of *Away* is based upon the findings and gained knowledge from the pre-study. The usage design predominantly promotes the primary use of *Away* although the secondary and side use of the cooler also was taken into account. The preparation of the final design concept is visualised through an Hierarchical task analysis (HTA), see Appendix X. HTA, and consists of less steps than most of the competitor products. Initially, the user freezes the ice pack. When frozen, the ice is to be put in the medical cooler's ice compartment. The desired amount of medication is thereafter placed in the two medical compartments, each with the dimensions 180 x 41 x 200 mm. By closing the two lids of the medical cooler, a rubber list is compressed and enables an airtight locking of the cooler. Two devices are then easily pushed to the sides on top of the medical cooler, which enables the locking mechanism of the cooler. *Away* is then ready to be carried in either manner the user chooses, by its handle or its shoulder strap. The usage of *Away* can be seen in Appendix XI. Usage of *Away*.

The design and dimensions of *Away* facilitates an easy transportation to the airport as the medical cooler can be placed in car trunks or at overhead compartments on the bus or train. When at the airport, *Away* can be easily carried using the handle or shoulder strap. As there seldom are any longer distances to travel by foot at the airport, the design of *Away* also benefit from a standing position as well as being easy to grab on-the-go or to swing up on the shoulder. The potential opening of the cooler in the security screening is eased by a simple locking mechanism, described in the previous paragraph, and enables a quick and efficient screening of the content. On-board the flight *Away* is to be lifted by its handle in order to easily place the cooler in the overhead compartments. The departure from the airport to the destination is to be carried out in similar manners as the arrival to the airport.

The use of *Away* performed by secondary users is eased by the adjustable shoulder strap, which enables relatives or travel companions to carry the medical cooler when needed. Another secondary use is the potential usage of the product when not transporting biopharmaceuticals. This usage is not especially designed as the medical compartments are in favour to the primary usage, yet it is not hindered. The secondary usage may include carrying food or beverages on the travel destination, which is not obstructed by the design of *Away* but may be limited.

5.4 MANUFACTURING & DESIGN

5.4.1 Materials

From the study of materials performed in the pre-study, appropriate materials were taken under consideration and the following paragraph presents the selected materials based on findings from the pre-study and the comparison to the list of requirements and guidelines.

The outer container was chosen to consist of acrylonitrile-butadiene-styrene (ABS) plastic. The material was beneficial due to its price worthiness of 1.50-2.80$/kg, thermal conductivity of 0.18-0.33W/(mK), density 1.01-1.21 Mg/m^3 and other properties that were beneficial for the application. Concerning environmental aspects, ABS possesses a medium recycle potential (Ashby and Johnson, 2010) and may be down-cycled, placed in landfill sites or combusted for energy recovery (CES EduPack 2009).

The cooling media was chosen to be ice with transparent plastic. The plastic was selected to be high-density polyethylene (HDPE) due to its transparency, price worthiness (1.10-4.00$/kg) and food grade properties (Ashby and Johnson, 2010). Thus, the HDPE plastic is non-toxic, a property almost all generic ice packs possess. Regarding environmental aspects, HDPE has high recycle potential (Ashby and Johnson, 2010) and may be down-cycled or deposited in landfill sites (CES EduPack 2009).

The insulation of *Away* was chosen to be cellular plastic as it has satisfactory thermal conductivity as well as a low density and thereby saves weight to the overall medical cooler. The cellular plastic that meets the requirements the most adequate is expanded polystyrene (EPS), which also has the lowest thermal conductivity, 0.033-0.036W/(mK) as well as lowest CO_2 footprint of the four potential cellular plastics for the application; EPE, EPP, EPS and XPS. EPS is recyclable and may be safely deposited in landfill sites, down-cycled into materials with lower quality or combusted for energy retrieval. (CES EduPack 2009)

5.4.2 Manufacturing

The ABS and HDPE plastics are both easily moulded and could with benefit be injection moulded or polymer cast for the desired design of *Away*. According to Ashby and Johnson (2010), injection moulding is economically suitable for batch sizes ranging from 10000 to 1000000 whereas polymer casting is economic for batch sizes from 10-1000. The polymer casting is therefore beneficial to use if the medical cooler is not to be mass-

produced. Both manufacturing methods are suitable in order to produce the design of *Away* as the selected materials, material thickness and overall dimensions are within specifications of both methods (Ashby and Johnson, 2010).

The EPS is manufactured by mixing pearls of polystyrene, which absorbs a blowing agent, most commonly pentane. The mixture is expanded using steam. The expanded foam may then be expanded foam moulded, injection moulded or polymer cast (Ashby and Johnson, 2010). As the EPS act as insulator in the design, the ABS and EPS may need to be moulded simultaneously.

5.5 THE IMPROVEMENTS OF AWAY

Away is designed in order to improve the quality of life and experience of the product for users travelling with biopharmaceutical medicines. The design benefits these users in several aspects as well as aiding the secondary and side users of the product. The following sections describe how the issues of user experience, cooling capacity and quality were approached and implemented in the design. The evaluations of the concept is declared in chapter *6. Evaluation*.

5.5.1 User Experience

Primary Users

Away is developed to provide an improved packaging layout, which is intuitively designed and organised in order to promote a simple packaging procedure of the medical cooler. The medicine is thereby presented in a neat and structured way with aim to enhance the feeling of a safe transportation. The two medical compartments are dimensioned to provide enough space for several medicine packages, which enables a more flexible alternative than today's medical coolers. The packaging procedure includes fewer steps, which reduces the time consumption. Regarding the ice pack, the experience is improved by applying a soft strap on top of the pack as a handle. This enables the users to handle the ice pack without having to touch the cold surface of it. It also provides a qualitative look upon the otherwise simple ice pack. The ice pack is also marked with recommended freezing duration as well as being transparent in order to be able to check if the ice has frozen or not. Concerning the user issues associated with the airport security, *Away* is designed to ease the screening and risk of confiscation of the cooling media, see paragraph Secondary and Side Users, and thereby facilitates additional confidence and patient security to the users.

Additionally, *Away* is designed to improve the feedback given to the users and making them feel more in control of the product by featuring a gadget. Furthermore, the cooling capacity of *Away* is developed to increase the performance and thereby the reliability with the aim to fulfil a cooling duration of 24 hours. The design is evaluated concerning its functionality in chapter *6.1.3 Cooling Capacity*.

Secondary and Side Users

For the secondary users, the experience of the product is somewhat improved as *Away* possesses an adjustable shoulder strap, which enables an easy and comfortable transport of the medical cooler. The user experience for the side users are more distinctly improved

as the neat and structured interior layout with aim to enable the security personnel to easily review the content of the medical cooler as well as easily screen the ice pack and its content. The marking of the ice pack define the content and the transparency will further clarify the ice's authenticity. The improvements were conducted to reduce the duration the security personnel need to screen the medical cooler and the duration the medical cooler need to be open, which thereby will save some of the cooling capacity.

5.5.2 Cooling Capacity

Away facilitates an elaborate cooling capacity by possessing materials with good thermal conductivity as well as a generous insulation thickness. The volume of the cooling media is optimised through empirical tests and all together enables an increased cooling capacity compared to its competitors. The closure of the lids is made airtight due to the implementation of a rubber list along the gaps of the lids. Furthermore, *Away* is volume effective and thereby encapsulate low amounts of air inside. Thus, the cooling media do not need to cool a large quantity of air, which prolong the cooling duration.

5.5.3 Quality

Through the improved user experience and cooling capacity, *Away* facilitates a higher degree of quality compared to its competitors. Quality include among other dimensions; performance, reliability, environmental impact, maintainability, durability and appearance (Bergman and Klefsjö, 2010). Through the material selection of *Away* the impact resistance, CO_2 footprint and surface properties are carefully taken into account, which enables an improved quality of the cooler. Through the improved reliability and performance in terms of cooling capacity and overall design, *Away* also contributes to an improved patient security, which is a factor that both users and pharmaceutical companies value and it may thereby be regarded as a measurement of quality as well.

6 EVALUATION

The final concept *Away* was evaluated from the four perspectives; functionality, usability, sustainability and manufacturability in order to validate that the concept met the set of requirements and guidelines. The evaluations were based upon prototype testing, questionnaires and focus group interviews as well as computer-simulated scenarios of the manufacturing and the product's life cycle. The main focus of the evaluations was to validate the design, the user's impressions of the product concept and to identify possible improvements for further development. The evaluation performed with users aimed at evaluating the subjective values of the concept whereas the computer-simulations and prototype testing aimed at the more objective values such as functionality and manufacturability.

6.1 PROTOTYPE EVALUATIONS

In order to properly evaluate the cooling capacity and user impressions of the concept, a functional prototype was created. The prototype was built of materials that had similar dimensions and thermal properties as the materials selected for the concept. To be able to evaluate the prototype from a user perspective the prototype possessed the concept's dimensions to greatest possible extent, an adjustable carrying strap, a handle and a locking mechanism. The thermal properties as well as the design features were regarded as important in order to obtain a qualitative outcome of the evaluation sessions.

6.1.1 Prototype

The functional prototype was built of plywood and contained glass wool as insulator since these materials had similar thermal properties, 0.13 W/(mK) and 0.040 W/(mK) respectively, as the materials selected for the concept, which has thermal conductivity of 0.18-0.33 W/(mK) and 0.035W/(mK) for the ABS and EPS respectively.

The prototype was then surface treated using spackling paste and spray paint in order to create a pleasing finish. The prototype was also featured with an adjustable shoulder strap, locking mechanism and handle. Details regarding the prototype's appearance and construction, see Appendix XII. Final Prototype.

6.1.2 User Impressions

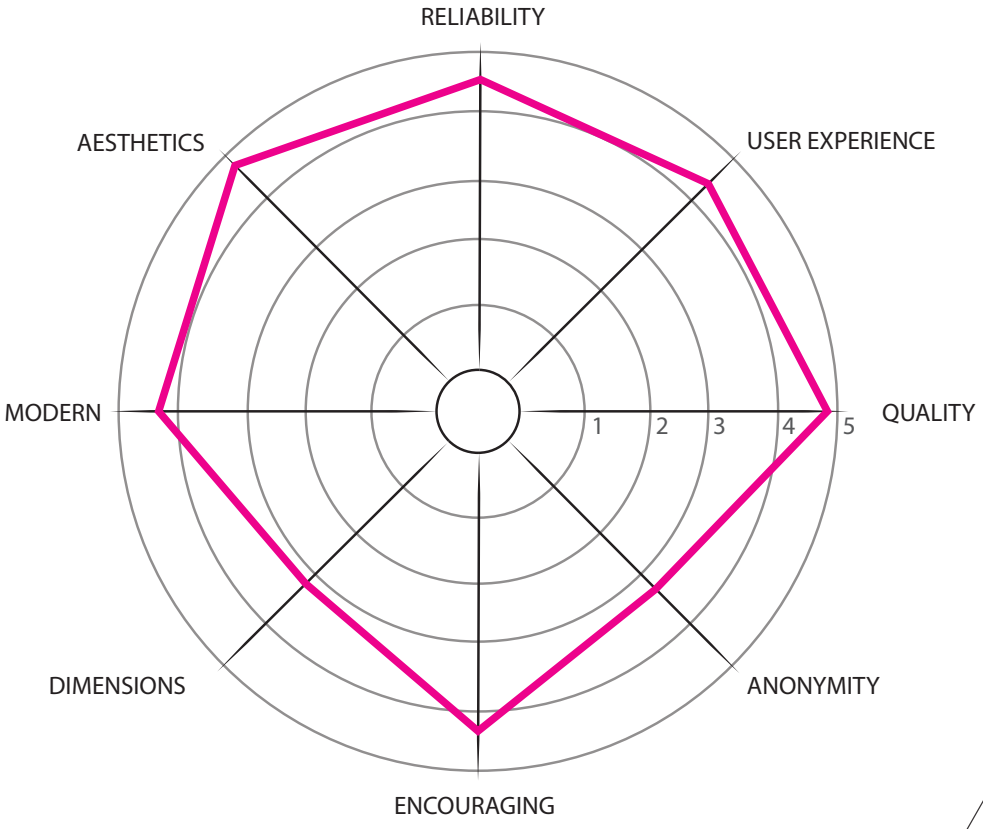
The user experience and usability of the concept was during a focus group evaluated by allowing six potential users to review renderings of the 3D model as well as to interact, use and study the prototype. The users were presented with several 3D renderings in order to create a perception and opinion of the concept. The users were then asked to answer a questionnaire and rank questions regarding impressions, opinions regarding the concept together with evoked emotions. They were thereafter asked to interact with the prototype and to answer an additional questionnaire regarding the usage and product experience by ranking statements. The results were compiled in radar charts, see figure 21. For further details and statistics, see Appendix XIII. Focus Group Questionnaires.

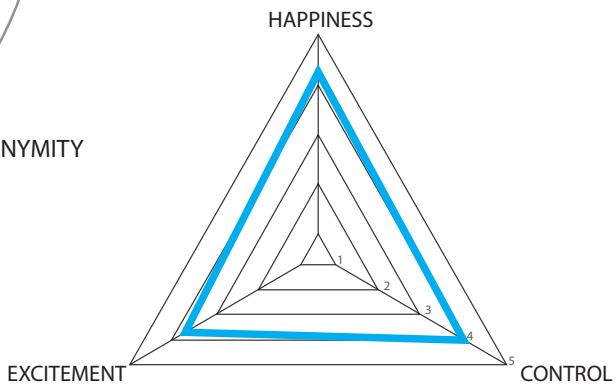
The results of the visual user evaluation, in which the participants were assigned to look at printed 3D renderings, indicated that the concept was regarded as highly qualitative and reliable. The aesthetics of the overall concept were graded highly with marginally lower results for the gadget. The findings also highlighted that the design of the cooler admitted the desired expressions caring, encouraging, flexible and confidence to a high

FIGURE 21. Radar charts based on the results of the user evaluation.

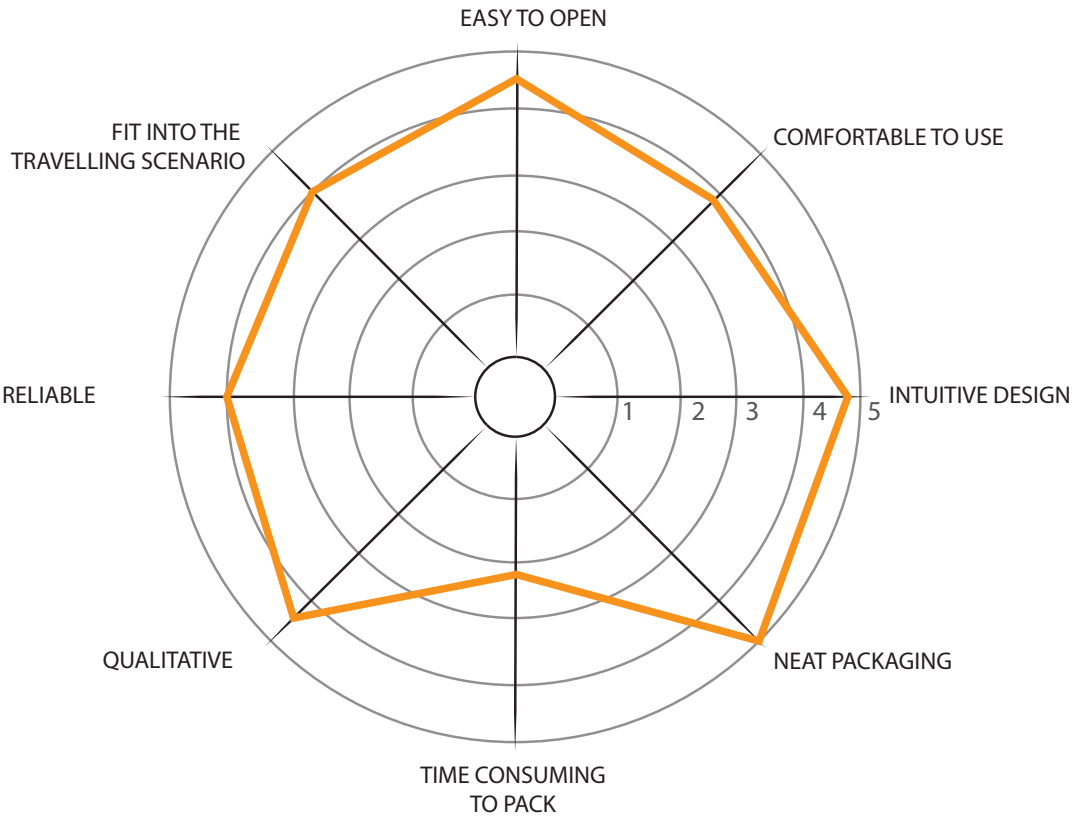
USER EVALUATION

3D RENDERINGS





PROTOTYPE



degree. When asked upon evoked emotions by reviewing the renderings, both high degrees of happiness, excitement and control were elicited. However, one participant graded the control as the minimum level and explained it by being anxiety-ridden regarding the overall use of medical coolers. The dimensions of the medical cooler were graded as mediocre, an aspect that might have to be reviewed further. The dimensions of the gadget were however regarded as pleasing.

Concerning the phase of the evaluation where the participants interacted and used the prototype of the medical cooler by performing a packaging and carrying scenario the concept was rated as easy to open and simple to use. The design of the cooler was rated as being intuitive and that it possessed a neat packaging layout, which was said to enable a less time consuming packaging procedure. The concept was also appreciated by the participants due to enabling a feeling of reliability, durability and quality. All participants of the focus group stated that they would use the cooler when they travel and that they would feel comfortable to use it. The cooler was also considered to fit into a travelling scenario. All participants also claimed that they would prefer *Away* instead of other coolers. Regarding the economic aspect, all participants stated that they would be willing to buy the cooler for an estimated cost of SEK 1.500, although 50% of the participants would also prefer if the cooler were sponsored. The 50% that did not want the cooler to be sponsored elaborated the statement with the risk of a reduced feeling of quality if the cooler were free of charge. Concerning the aspect of using the cooler in other contexts than to transport medication, 67% of the participants claimed that they would prefer if the cooler was aimed just at the medical situation.

Overall, the results of the user evaluations were highly satisfactory and corresponded well with the set requirements and guidelines of the product.

6.1.3 Cooling Capacity

In order to evaluate the cooling capacity of the final concept, the prototype was subject to testing. The prototype was prepared with 800 g of ice, which corresponds to the amount defined for the final design concept *Away*. Six empty medicine packages were then allocated in the medical compartments and one of them contained the thermometer sensor. The location of the test was the same as in previous tests. The ambient temperature during the test was 24°C.

The results of the test indicated that the prototype could hold within the desired temperature span for 18 hours before it reached 8.0°C. The temperature of the prototype was appreciable more stable than measured in the tests performed during the pre-study. The lowest recorded temperature was 5.9°C, which is far above the minimum limit of the medical cooler. The evaluation of the prototype thereby indicated that the outer insulation and construction facilitated a stable environment inside the cooler and that it may be able to hold for even longer durations if the lowest recorded temperature could be adjusted to reach closer to the minimum limit of 2°C.

The fact that the temperature did not drop below 5.9°C could be explained by a too generous thickness of the wall separating the medicine from the cooling unit. The thickness may insulate more than desired, which would hinder the temperature to drop even further. This finding proposes that a reduction of the insulation wall could be beneficial for the concept regarding the cooling capacity. Thus, a reduction in the total width of the cooler would be achievable, which is a factor that would improve the ergonomics of the cooler even further.

The findings from the functional evaluation was very satisfying as the prototype of the cooler kept a stable temperature within the desired temperature range for 18 hours and did not drop below the minimum limit as several of the tests conducted during the pre-study did. Thus, the results indicate that the construction is elaborate and that it enables an improved stability of the temperature during a long period of time. The design of the cooler has thereby met all the key requirements of the product with exception for the duration of the cooling period. The possible interventions to improve the cooling capacity are further discussed in chapter 7. *Discussion.*

6.2 SUSTAINABILITY

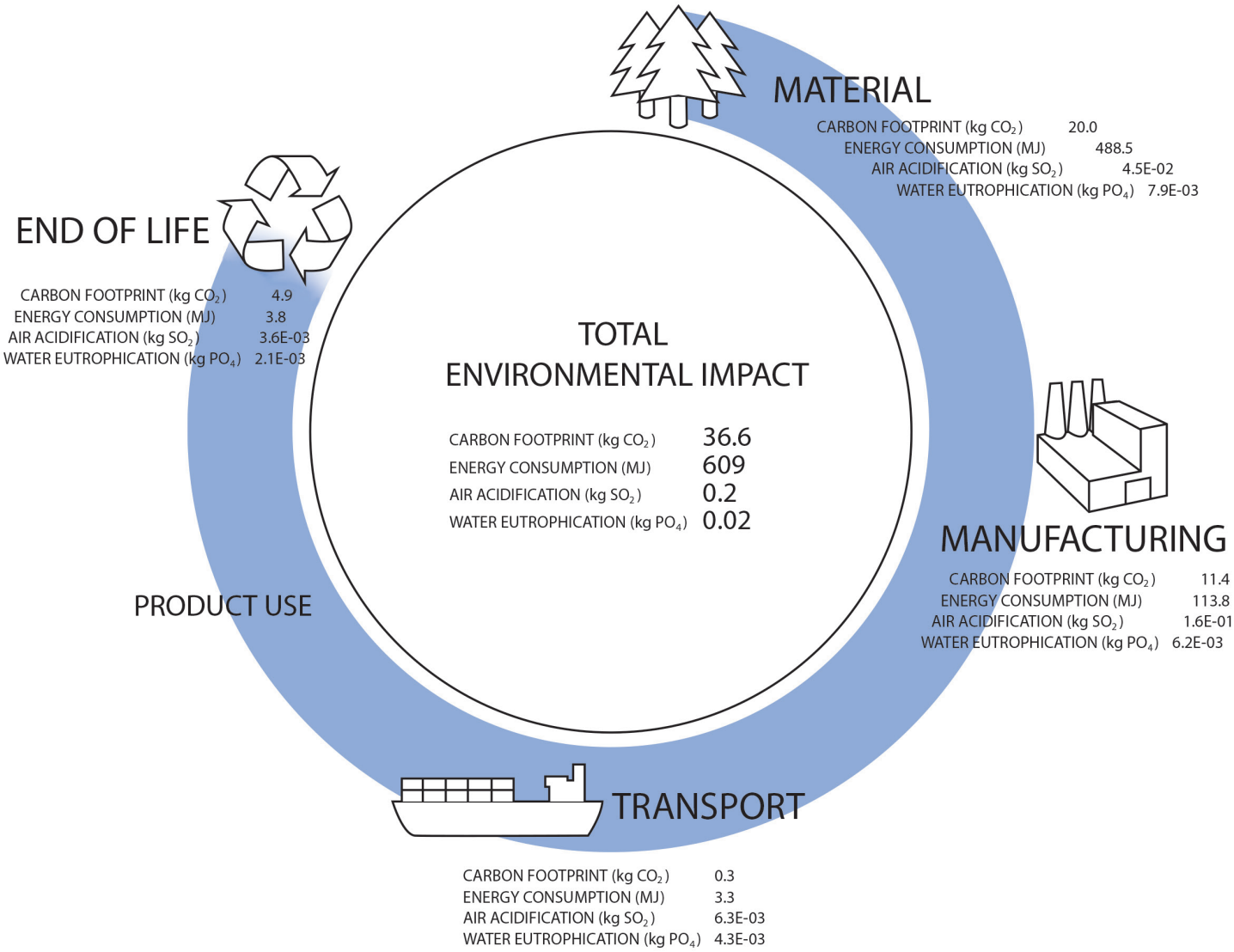
The evaluation method concerning sustainability and environmental impact was chosen to be Streamlined life-cycle assessment (sLCA) and was conducted using computer software. The created CAD model was assigned with accurate materials and was given an array of simulated parameters from which the software calculates the environmental impact. The manufacturing method was set to injection moulding, the geographical location of manufacturing was selected to be Asia and the usage location in Europe. The manner of transport to the usage location was chosen to be by container ship and the expected lifetime was simulated to be 5 years. The aim of the evaluation was to gain insight in what environmental impact the medical cooler has and which part of the product's life cycle that was the largest contributor to the effect.

The environmental impact, simulated by the aforementioned scenario, are divided into the four categories, carbon footprint (kg CO_2), energy consumption (MJ), air acidification (kg SO_2) and water eutrophication (kg PO_4). The environmental impact of each phase in the product's life-cycle can be seen in figure 22. The results of the simulation indicated that the material phase of the product's life-cycle was the largest contributor to the environmental impact with a total of 78.7% of the entire impact. This could be explained by the large emissions of carbon dioxide and large amount of energy needed for the material extraction. The total carbon footprint of the product amount to 36.6 kg CO_2, which corresponds to the amount of emission produced by approximately 9 MacBook Air (Apple, 2012). The total energy consumed was found to be 609 MJ, which is equivalent to 169 kWh. For detailed data concerning the environmental impact, see Appendix XIV. Environmental Impact.

Concerning the environmental impact of the materials, ABS and HDPE was regarded to hold satisfactory properties and values of carbon footprint and recyclability. According to the software CES EduPack, both plastics may be down-cycled, combusted or placed at landfills, qualities that from an environmental perspective were considered adequate. Regarding the large impact from the material phase the extraction of material may be seen as inevitable due to the set requirements of the product. However, the amount of extracted material contributed the product's total weight of 3.460 kg.

FIGURE 22. Simulation of the carbon footprint, energy consumption, air acidification and water eutrophication.

ENVIRONMENTAL IMPACT



PART OF THE TOTAL IMPACT

MATERIAL 78.7% MANUFACTURING 19.4% TRANSPORT 0.55% END OF LIFE 1.35%

6.3 MANUFACTURABILITY

6.3.1 Design

The different parts of the final design concept *Away* were evaluated more thoroughly in order to determine if there were any potential flaws in the design or if the design in any way could affect the manufacturing process in a negative manner. The detailed results of the evaluation can be found in Appendix XV. Design Evaluation.

The evaluation of the design indicated that the overall design was of sufficient thickness of 2 mm in order to be able to use injection moulding as manufacturing method. However, some potentially critical thickness were identified. The critical points in the design were mainly critical edges and radii. None of the identified critical points was to be regarded as contributing to severe consequences for the manufacturing method.

The design of the handle contributed to the largest quantity of critical points, mainly due to narrow radii setting and thickness below the required 2 mm. These aspects may be object for refinement if the product was to be manufactured in order not to affect the process negatively. Another large contributor to the critical points was the hinges and their surrounding surfaces. These may, in conformity with the handle, be redesigned in order to be suitable for the injection moulding.

All potentially critical points should be reviewed before a manufacturing process can be initiated.

6.3.2 Dimensions

The dimensions and proportions of *Away* were evaluated in order to evaluate the design towards influencing regulations, relevant anthropometric data and to identify potential incorrect dimensions.

Concerning the evaluation of influencing regulations, the dimensions of the medical cooler was restricted by the size recommendations of a carry-on luggage, 450 x 250 x 560 mm, which was one of the key requirements on the product. The size of *Away* was within the recommendations as it has the dimensions 244 x 198 x 298 mm.

Another key requirement was to fit the ice pack into a commercial freezer in order for the user to easily freeze the ice pack at home or at the destination. The ice pack designed for Away is generally based on measurements of two generic ice packs, 178 x 38 x 198

mm, and should thereby be able to be fit into a commercial freezer. Concerning freezers located in for instance hotel rooms, the size of the freezer may vary and it is therefore difficult to predict whether or not the ice pack will fit inside. However, the possibility of freezing the ice pack in the hotel's own facilities may be regarded as high. Concerning the tolerances of the ice pack compared to the ice compartment the evaluations indicate that they were sufficient as the tolerances were set to 2 mm in every direction.

The dimensions of the medical compartments corresponds to the key requirement to fit 5 doses of biopharmaceuticals inside the cooler. Each medical compartment has the dimensions of 180 x 41 x 200 mm, which corresponds to 3 and 4 doses of Avonex and Humira respectively. The medical cooler thereby enables the transport of 6 and 8 doses respectively.

Another requirements that concern the area of dimensions was the ergonomic requirement to design the cooler in accordance to anthropometric data of the 5th and 95th percentile female and male. The handle was found to fit the hand sizes of the 5th percentile women and 95th percentile men, which therefore targets a large population. Thus, the users of the target group should be accounted for. The shoulder strap's dimensions were also satisfactory as the length of the strap was adjustable and the pad of comfortable size for various widths of the shoulder. Concerning the lock, the devices were found to be of good dimensions as they were easy to handle and to grip. The dimensions of the total width was the aspect where the ergonomics were regarded as the most troublesome since the medical cooler are to be carried on the shoulder or cross body. The width of the cooler contributed to a less ergonomic carrying manner than desired. The width may therefore be recommended to review and develop further.

Suggested design improvements regarding the medial cooler's dimensions can be found in chapter 7. *Discussion.*

6.3.3 Manufacturing

The results of the evaluations of the design and dimensions indicated that the selected manufacturing method, injection moulding, could be applicable and suitable for the current design. The evaluations did not identify any major flaws that would hinder the use of injection moulding. However, some smaller refinements may be necessary to some features of the concept in order not to affect the manufacturing process in

a negative manner. As mentioned in chapter *5. Final Concept*, injection moulding may be regarded as non-economical for small batch sizes. The manufacturing method may therefore be altered to polymer casting if a large batch size is economically indefensible. The performed evaluation has however been conducted with the approach that injection moulding was the selected process.

Regarding the design of the insulation, the outer and inner plastic shell encapsulates the insulation in order to guarantee a consistent insulation thickness. The different materials might be subject to a concurrent moulding process to be able to reduce the risk of creating air leakage in the cooler between meeting surfaces. The manufacturing blueprints of the concept *Away* can be found in Appendix XVI. Blueprints.

Overall the evaluations of *Away* indicated that the design only require smaller and simpler kind of redesign. Proposed design refinements may be found in the discussion.

6.4 EVALUATION SUMMARY

6.4.1 Fulfilment of Requirements

The evaluation towards the list of requirements indicated that the majority of the requirements and guidelines has been fulfilled by the final design concept *Away*. For further details, see appendix XVII. Fulfilment of Requirements.

6.4.2 Fulfilment of Goals

The master's thesis reached the desired depth and content set for the product development project. The final concept *Away* demonstrates the potential to develop and improve a medical cooler through product design. The improvements benefits the users travelling with biopharmaceuticals in several aspects as well as aiding secondary usage. The concept of a hard-shelled medical cooler for personal usage that possess appealing aesthetics and provide the user feedback through a thermal control gadget is a product that clearly differentiates itself from its competitors.

According to the user evaluation the results of the usage and interaction as well as the aesthetics were highly satisfactory, which fulfils the key requirement of delivering an intuitive and user friendly design. The main concern regarding the user friendliness is that the users regarded the dimensions of *Away* as mediocre.

Since *Away* only possess traditional thermal technology and a cooling media that is readily available on the market it is likely for the product to be realisable within the next three years, which is one of the key requirements set for the master's thesis.

Regarding the financing of the product, it should be discussed further since findings indicate a scattered user group regarding the issue. There may be possibilities for the product to be financed as a sponsored or semi-sponsored product which would make the product more price competitive.

Even though the findings from the functional evaluation showed that the prototype did not fulfil the requirement of possessing a cooling capacity of 24 hours within the desired temperature range, the evaluation indicated that the prototype possessed an improved stability of the temperature during a long period of time. The stability of the temperature indicates a great potential of developing the concept further in order to reach the set goal of possessing a cooling capacity of 24 hours.

7 DISCUSSION

The discussion chapter highlights, comments and explains interesting findings and aspects of the master's thesis. The discussion aims at highlighting the selection of methods, the uncertainties associated with the performed tests and how the project could have been executed differently. The chapter also emphasise the relations between expected and actual result as well as the pros and cons of potentially being a commercial product and the possible secondary usage of it. The limitations of the project are also discussed and how these might have influenced the final result. Suggestions of design improvements and further development are listed and the report is summarised by presenting the conclusions of the master's thesis work.

7.1 GENERAL DISCUSSION

7.1.1 Method Discussion

Process

The main goal of the master's thesis is to improve the cooling capacity of the medical cooler and the ideation was therefore initiated by exploring ideas of how to optimise the thermal technology and interior layout. The ideation was then proceeded by exploring ideas of exterior designs based on the concepts of interiors and thermal technology. The design process of this master's thesis was based on a from the inside-out structure where the exterior design was created depending on the interior layout and thermal technology in order to optimise the cooling capacity and user friendliness. The from the inside-out approach influenced the selection of methods as the concept was defined step by step instead of becoming a handful of concepts to evaluate.

Methods

As the aim of the master's thesis is to develop an elaborate concept of a medical cooler within a rather short period of time it was important to prioritise the field of study and some aspects are therefore researched more briefly. The methods used in the pre-study were focusing mainly on identifying the users, defining the use scenario and detecting possible areas of how to improve the product.

The methods used were a combination of objective and subjective methods in order to create a more nuanced interpretation of data and the overall product segment. The selection of methods is thought to enhance the user's perspective on the product in order to create a more satisfying design that would be created with the user in focus.

Selecting the Final Concept

When selecting the final concept different features were compiled and combined in a similar way to a morphological matrix. The selection of the final concept could have been conducted in a more methodological manner by creating a handful of concepts for evaluation and selection of the best one by using different methods. However, the concept development was to some extent non-traditional as the packaging layout of the concept was defined before the exterior. The evaluation method of the exterior was therefore made from a subjective perspective combined with relevant findings from the pre-study. The benefit of the conducted manner is that the subjective aspect was allowed to take place in the selection as well as the requirements and guidelines.

User Studies and Participants

During the interviews and surveys a lot of important feedback were obtained, which gave the project a depth and insight within the area of travelling with medication. The participants were very helpful and took great interest in the project in order to contribute to the development. In the online surveys the respondents were both Swedish and international users of medical coolers. The amount of respondents in the online surveys were more than expected, which gave the project a pleasing result. It also resulted in the use of just complementary interviews during the pre-study instead of having interviews as the key method. However, as the primary users of this project is a rather small and specific group it was quite time consuming to get in contact and much effort was allocated in order to reach out to them both nationally and internationally.

The final focus group session was of great importance in order to evaluate the functional prototype. Since the focus group only consisted of six participants it might have made an impact on the results of the functional prototype evaluation. One potential change in the method would have been to conduct two sessions and perhaps to include secondary and side users as well in order to evaluate the concept more thoroughly.

Regarding the selection of participants, the user group was limited to users prescribed with Humira and Avonex in order to narrow the user group. The selection was based on the author's previous knowledge about biopharmaceuticals. A larger user group would perhaps have been beneficial during the user studies but would also have been more time consuming and could potentially have contributed to a more unspecific user persona, which in turn could have contributed to a more difficult ideation process. The selection of a narrow user group was in retrospect a good choice since the project provided insight in the difficult issue of creating a solid design for all biopharmaceuticals.

Experimental Uncertainties

Potential experimental uncertainties during the tests of the cooler bags and functional prototype was for instance the accuracy of the measuring equipment. In order to record the cooling time a thermometer was used that measured the temperature both inside the medical cooler and the ambient temperature in the room. Since the thermometer was designed for domestic use the accuracy might have impacted the results. Changes in the ambient temperature of the room might also have affected the results. Another uncertainty was connected to the fact that the functional prototype was home-made.

7.1.2 Result Discussion

Expected Result compared to Actual Result

The expected result and the actual result of the master's thesis differ to some extent regarding the cooling capacity. However, concerning the theory and research behind the cooling capacity there are strong similarities to the expected and actual result. The actual result from the pre-study where the thermal technology tests were performed correlates to the research of others, for instance Williams and Bishara (2010) who state that a separation of the cooling units and the payload are necessary. The result of the pre-study indicate that an insulating wall improved the temperature's stability within the cooler. The insulating wall between the cooling media and the medication also improved the cooling capacity as more cooling media could be added to the packaging layout. The expected result of the prototype test, founded in the results of the pre-study, connects to the actual results with exception to the duration of the cooling. The cooling duration differed to the expected result with respect to the narrow drop in temperature of the functional prototype. The expected result was that the temperature would drop to 2°C and then rise to the maximum limit of 8°C. The actual result was a drop to around 6°C and then a rise to 8°C. However, as the cooling duration within the temperature span of 6-8°C were highly satisfactory, the potential of prolonging the cooling capacity by allowing a range of 2-8°C is regarded as great.

The difference between the expected and actual results is regarded to potentially be caused by a dimension error regarding the insulation between the medicine and cooling unit. However, as the actual result is based on a home-made prototype, the difference of the expected and actual result may very well be caused by errors made during the building of the prototype. The insulation used could potentially be packed in a manner different from the optimal one during a manufacturing process. The thickness of the plywood, which is thicker than the plastic in the CAD models, could be a contributing factor to the result as well. The design of the prototype and the CAD models also differ to some extent regarding the enfoldment of the lids and the insulation of the interior, which may have contributed to a greater air leakage than it would if manufactured by injection moulding and according to blueprints.

Sponsored or Not?

The final concept of the medical cooler can potentially be a sponsored product, which is then offered to the patients in the same manner as today. Estimation in cost was done

with aim of investigating the willingness to pay for the cooler instead of receiving it as a free product by the health care. The findings of the user evaluation indicate that a strong majority of the participants are willing to buy the cooler for the estimated cost of SEK 1.500. From a pharmaceutical company's perspective, the cost is potentially over budget as a too large sponsoring legally is regarded as a bribe. Regarding the issue whether or not the product should be sponsored, the result of the user evaluation indicated that the participants regarded the product to possess greater reliability and quality if not sponsored. This standpoint may need to be investigated with a more statistically based finding before a conclusion can be drawn. However, the viewpoint is interesting and well worth considering regarding the pros and cons of a sponsored product.

Potential Customers

The target customers is mainly users prescribed with temperature sensitive injection pens but the product may also be purchased by for instance a relative to be given away to a family member. The target customers are users that appreciate and value a high quality medical cooler that is reliable and is designed to fit a traveller. Regarding the target users' travelling habits, *Away* will most likely be successful within the area of users who travels to far of destinations and/or for long durations. Since *Away* is optimised for carrying larger amounts of medication it will not target users travelling within shorter distances and sojourns, 1 - 2 weeks, to the same extent with reservation that the user only uses one type of medication. If several medications are used simultaneously, there might be an increased demand for the cooler even during shorter travels of 1-2 weeks since its compartments are designed to transport a large amount of medication.

Secondary Usage

A secondary use of the medical cooler would potentially be beneficial for the product as it could be used more often and thereby serve a greater purpose. The users who participated in the focus group evaluation did however regard it as beneficial if the medical cooler is to be used only for transport of medicines. The concern is interesting as it has similarities with the issue of being sponsored or not. The reliability and quality of the medical cooler seem to be improved if the cooler isn't free of charge and when it is targeted at one specific market.

If a secondary use context is off the table, a potential rescue for the possibly small market could be to also target the product towards pharmaceutical representatives. The medical cooler would then still be targeted at medical situations but would have

an increased market potential. An increased user group would also benefit the choice of manufacturing process, as injection moulding is an expensive method if the batch sizes are small. However, the medical cooler has not been object to thorough analysis or evaluation concerning this potential usage and the subject should therefore be looked into further before the suitability of the medical cooler in that specific context can be determined.

Area of Great Improvement Potential

The findings of the master's thesis do add to the research in the field of medical coolers in several ways. However, not by new technology but through highlighting the impact of small changes and innovative solutions in order to greatly improve the product segment.

Firstly, the findings indicate that it is possible with small means to improve the cooler's cooling capacity. The thesis has not contributed to any new thermal technology but instead highlights how to improve the layout of the packaging and insulation by small means in order to create a product with longer cooling duration.

Furthermore, the area of usability was found to be an area with great improvement potential, which could be achieved by small means of design changes foremost regarding the packaging layout of the interior.

Moreover, the medical coolers were found to have improvement potential concerning the aspects of reliability and quality. These are addressed mainly through the improvements regarding cooling capacity and usability, but also through changes in materials as it influence both the performance of the medical cooler and also the overall user experience and impression of the product.

In addition to this, an aspect highlighted by the pharmaceutical company AbbVie, was the importance of keeping and enhancing the patient security. This aspect was found to have a great improvement potential as some of the current products on the market did not fulfil the goal of transporting the medicine securely in accordance with the requirements set on the temperature span and the guaranteed cooling duration.

Lastly, the master's thesis adds to the area of research just by creating a dialogue with the pharmaceutical companies, as they are the current main actor today in this product segment. By reviewing their current products the companies may improve not only the

patient security of the medical coolers but also the user's quality of life in excess of just efficient biopharmaceutical treatments.

Product Differentiation

The final concept *Away* is clearly differentiated from its competitors regarding performance. The concept possess a prolonged cooling capacity compared to other non-powered coolers. The design of the cooler also enables a more stable temperature within the desired temperature range in contrast to the tested competitor products. The interior layout of the concept differentiates by possessing the cooling unit in the middle of the cooler. This prevents the unit to alternate position during the handling of the cooler, which is beneficial for the product's performance. Moreover, the product concept differentiate itself from competitor products by being a hard-shelled cooler in the model of a messenger bag, a combination that was not identified in the product segment during the competitor analysis.

Regarding the usage, the product concept features a structured packaging layout, which enables both a more easy packaging procedure and easy screening at the airport security than its competitors. The gadget of the concept *Away* enables a more thorough feedback than ordinary thermometers used in coolers today by predicting remaining time as well as displaying elapsed time. Furthermore, the gadget contains an alarm system, a feature which is not included in any of the investigated products on the market.

Limitations

Concerning limitations of the study, the delimitation of considering air travels as the main use scenario is known to have influenced the final design and outcome of the project and thereby contributed to limitations in the design and usage. The design is based on the regulations found concerning liquid medicine on airports and the recommendations concerning dimensions of carry-on luggage. If the main use scenario would have been another, for instance car travels, the product solution may have been different. However, the design of the final concept would not hinder the usage in a car or train but the solution might have looked different if the air travels were excluded.

Another limitation to the study is that the evaluations concerning the gadget and the locking mechanism of the cooler was not as thoroughly evaluated as the rest of the concept. The time frame of the project did not allow an equally thorough evaluation, as it would have been time consuming to create an accurate and functional gadget and

lock. Instead, renderings of the gadget and lock were used as evaluation basis during the focus group evaluations.

Another potential limitation to the study is that the actual weight of the cooler could not be evaluated with the users as the materials of the prototype and CAD model differ. This might be studied further in a more thorough user study.

Furthermore, a limitation of the study is that the product has not been tested in the correct environment associated with air travels. The changes in temperature and air pressure have therefore not been taken into account during the test sessions. Moreover, the cooling media of ice may be more difficult to use during cold ambient temperatures as it rather protects from warm temperatures. These are factors that might be looked into in a stage of further development in order to determine its influences on the product.

7.2 FURTHER WORK

7.2.1 Design Improvements

Overall, the design of the concept *Away*, is regarded as satisfactory as it fulfils the set goals of the product. The design flaws of the final concept is regarded as minor and mainly concerns design aspects such as dimensions, material thickness and critical areas that could affect the manufacturing process. The design proposals in order to address the concerned improvement areas are listed below:

- Reduce the material thickness of the insulation wall between the cooling unit and medicine in order to improve the cooling capacity's duration.
- Implement larger radii and reduce the occurrence of sharp edges in order not to inflict issues in the manufacturing process.
- Reduce the width of the cooler in order to enhance the ergonomics while carrying the cooler.

7.2.2 Further Development

The most beneficial continuance of the project is to enter an additional iterative cycle of refinement, analysis and evaluation in order to reach an even higher level of quality. The further improvement cycle would to a larger degree make the product ready for the process of becoming a product on the market. The following is a list of areas that are regarded to benefit the most from a further development:

- Usability testing to study how the suggested refinements could impact the ergonomic and usability aspect of the product.
- Functional tests of the product in order to explore if alternations in the construction could improve the cooling capacity further.
- Usage of the product in an air travel environment and thereby test the product design towards the primary user and airport security personnel.
- Further material evaluations in order to explore how to reduce the environmental impact of the product even more.

7.3 CONCLUSIONS

The outcome of the master's thesis is *Away*, a product concept of a medical cooler aimed at transporting temperature sensitive biopharmaceuticals on personal travels. The following conclusions can be drawn based on the results of the project:

- Overall, the product design of the medical cooler fulfils the goals set for the master's thesis with exception of the duration of the cooling.
- The cooling capacity of the medical cooler can be improved drastically compared with competitor products by incorporating small means of improvements concerning the packaging layout, insulation, material selection and design.
- The product's reliability, quality and usability can be improved by integrating small means of improvements to the design.
- The area of focus has great improvement potential and the medical cooler can potentially be additionally improved in a stage of further development.

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Figures and Tables

Figure 1:Avonex Pen package. *Photography.*

Figure 2: Cooler bags. *Photography.*

Figure 3: Cooling media. *Photography.*

Figure 4: Travel habits. *Illustration.*

Figure 5: Air travels. *Illustration.*

Figure 6: Use simulation. *Photography* and *Illustration.*

Figure 7: Packaging layouts. *Illustration.*

Figure 8: Test results. *Illustration.*

Figure 9: Inspiration board. *Composition.* Multiple owners;
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Figure 10: Potential packaging layouts. *Illustration.*

Figure 11: Early concepts. *Photography.*

Figure 12: Carrying manners. *Illustration.*

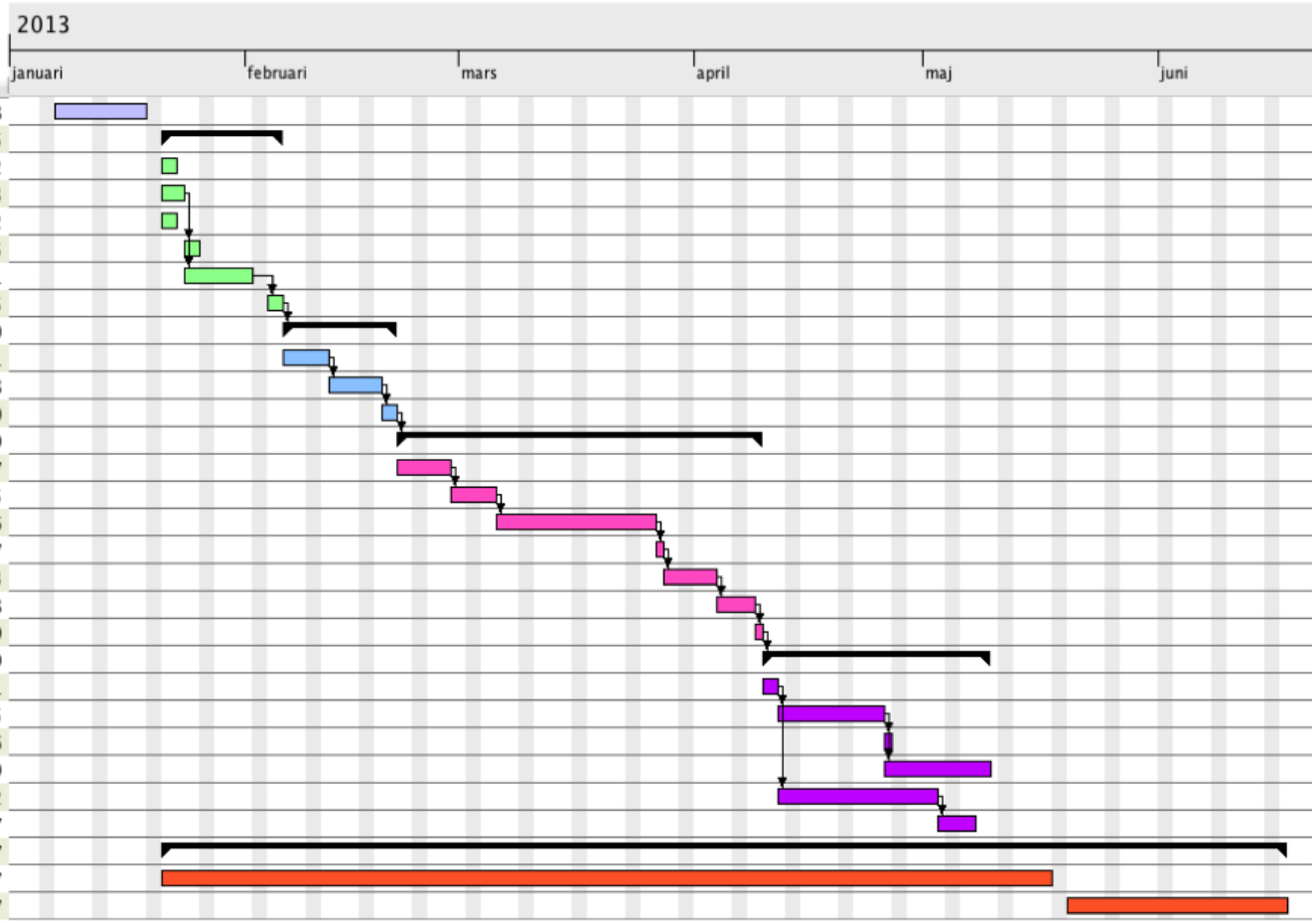
APPENDICES

APPENDIX I. TIME PLAN

PLANNING MASTER THESIS MEDICAL COOLER

Sofia Alvenby & Mikaela Rehnmark

Namn	Startdatum	Slutdatum
Start-Up	2013-01-07	2013-01-18
Phase 1: Demand Study	2013-01-21	2013-02-05
Background	2013-01-21	2013-01-22
Market Research	2013-01-21	2013-01-23
Standards & Regulati...	2013-01-21	2013-01-22
Technical Research	2013-01-24	2013-01-25
User Studies	2013-01-24	2013-02-01
Evaluation	2013-02-04	2013-02-05
Phase 2: Usage Design	2013-02-06	2013-02-20
Case Study of User Sc...	2013-02-06	2013-02-11
Usage Design	2013-02-12	2013-02-18
Evaluation	2013-02-19	2013-02-20
Phase 3: Ideation	2013-02-21	2013-04-09
Functional Concept G...	2013-02-21	2013-02-27
Visualization	2013-02-28	2013-03-05
Functional Prototyping	2013-03-06	2013-03-26
Evaluation Functional...	2013-03-27	2013-03-27
Form Concept Gener...	2013-03-28	2013-04-03
Evaluation	2013-04-04	2013-04-08
Selection	2013-04-09	2013-04-09
Phase 4: Final Concept &...	2013-04-10	2013-05-09
Refinement	2013-04-10	2013-04-11
Final Visualization	2013-04-12	2013-04-25
Manufacturing & Sust...	2013-04-26	2013-04-26
Final Rendering	2013-04-26	2013-05-09
Final Prototype	2013-04-12	2013-05-02
User Evaluation	2013-05-03	2013-05-07
Phase 5: Documentation	2013-01-21	2013-06-17
Report	2013-01-21	2013-05-17
Presentation	2013-05-20	2013-06-17



APPENDIX II. INTERVIEW GUIDE COMPANIES

Interview Guide - PHARMACEUTICAL COMPANY

LÄKEMEDEL
Vilka läkemedel tillverkar ni som ska förvaras i 2°C-8°C?
Hur känsliga är läkemedlen mot att vara över 8°C?
Vad händer om de ligger precis över denna "gräns"?
Finns det något på medicinen som indikerar att de förvarats för varmt/kallt?
Vilka dimensioner har originalförpackningarna av de aktuella läkemedlen?
Hur många patienter (på ett ungefär) är ordinerade dessa läkemedel?

KYLVÄSKA
Finns det någon kylväska som ni erbjuder idag? Vilken?
Om ja, har ni gjort egna tester på era kylväskor? Hur länge garanterar ni kyla?
Om inte, skulle ni vara intresserade av att sponsra en kylväska / rekommendera en specifikt produkt?
Hur många mediciner har ni tänkt att den ska rymma?
Om patienter hör av sig och frågar om kylväskor vart hänvisar ni dem? Varför just dit?
Har ni upplevt att era patienter tycker att det är ett problem med kylväskorna?
Vilka aspekter tycker ni på Abbvie är viktiga hos en kylväska?
Vad är viktigt ur marknadsföringssynpunkt?

Interview Guide - PACKAGING COMPANY

ALLMÄNT
Vilka material använder ni i era lösningar?
Vilka olika lösningar erbjuder ni era kunder?
Vilka kylmedier använder ni er av?
Vad kostar de olika lösningarna?
Hur kontrollerar ni att de håller korrekta temperaturer?
Hur görs valideringstesterna?
Finns det någon form av indikator som visar att det är korrekt temperatur?

Cellplaster, vilka erbjuder ni?
Fördelar/nackdelar?
Tillverkning, hur går det till att tillverka cellplaster?

APPENDIX III. COMPETITOR ANALYSIS

COOLER BAGS

COOLERS

ELECTRICAL COOLERS / MICRO FRIDGES

IMAGE SOURCES - COMPETITOR ANALYSIS

http://www.sunrek.com/photos/igloo/43586.jpg

http://www.coolicebox.com/shopimages/products/extras/SB1215.jpg

http://www.coolicebox.com/shopimages/products/extras/MD8L.jpg

http://www.coolicebox.com/shopimages/products/extras/MB%201500._800jpg.jpg

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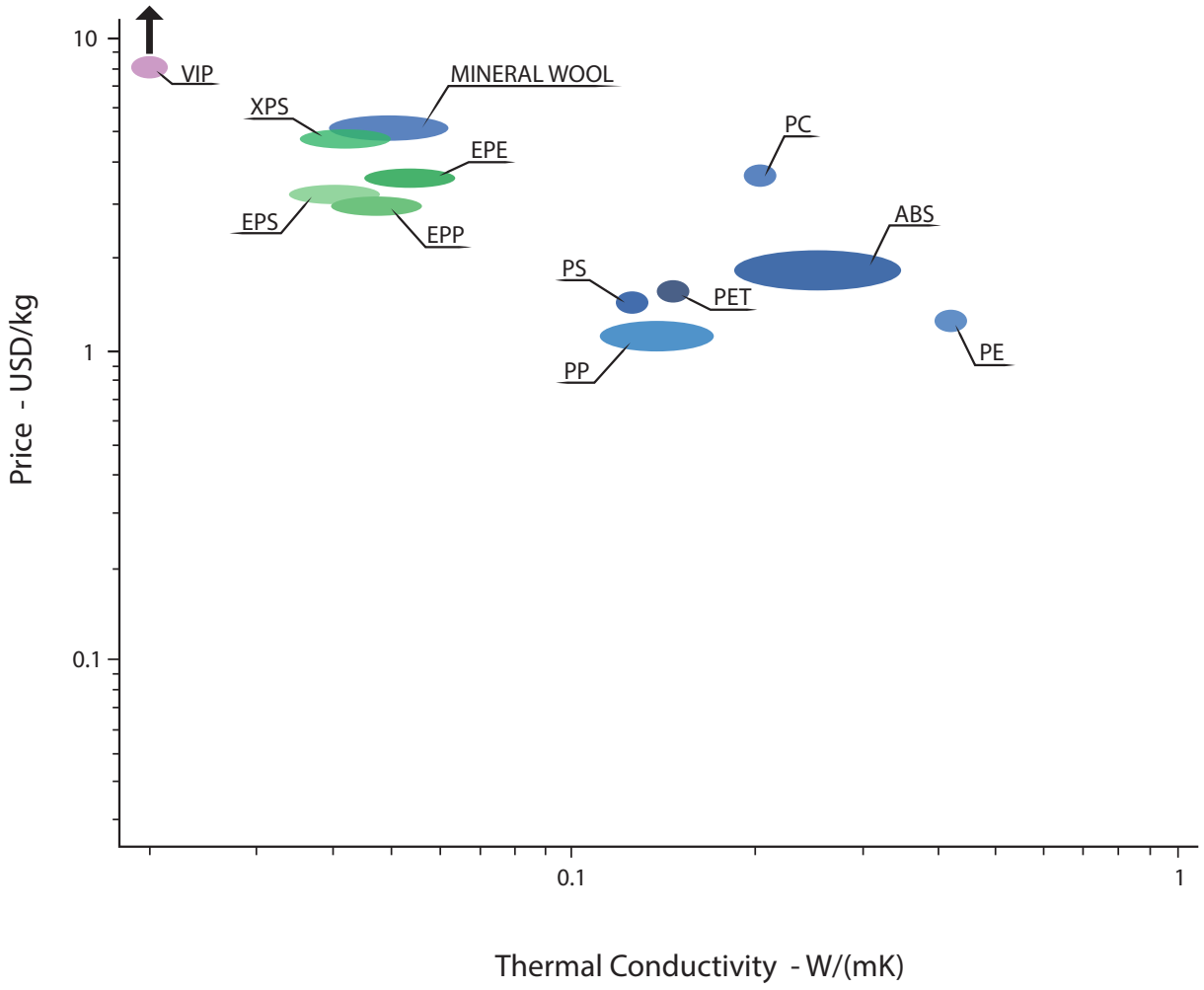
http://www.coolicebox.com/shopimages/products/extras/MB1700.jpg

APPENDIX IV. MATERIAL PROPERTIES



APPENDIX V. INTERVIEW GUIDE USER

Interview Guide - USERS

KYLVÄSKAN
Vilken typ av kylväska använder du idag? (Märke, sponsrad/köpt, ungefärligt pris)

PACKA & FÖRBEREDA
Hur många medicinförpackningar brukar du vilja ha med dig?
Får medicinen plats i kylväskan som ni vill ta med under resan?
Hur packas medicinen? Förklara stegvis hur du gör.
Hur stora är förpackningarna som ska packas i kylväskan?
Vad kan vara problematiskt med den nuvarande kylväskan?

ATT RESA
Har du någon gång undvikit att resa på grund av din medicin/kylväska?
Vad är viktigt att tänka på när man reser med din medicin?
Hur förbereder du dig vanligen inför en resa då du måste ta med dig din medicin? Beskriv.
Har du stött på några komplikationer under dina resor pga din medicin/kylväska? På vilket sätt? Varför?
Upplever du att kyltiden är tillräcklig för att nå din destination?
Har du någon gång känt dig orolig eller stressad över att kylväskan kanske inte ska hålla medicinen kyld ända till din destination?

ATT RESA MED FLYG
Vad krävs det för intyg för att du ska kunna resa med medicinen?
Har du någon gång stött på problem med säkerhetskontrollen då du reser med flyg?
Har du någon gång använt dig av flygplanets kylmöjligheter för att återkyla medicinen?

UTTRYCK
Vad tycker ni att er befintliga kylväska uttrycker?
Upplever du att din kylväska förvarar din medicin på ett säkert sätt? Varför/varför inte?
Hur viktig är kylväskans utseende för dig? Vad är viktigt/inte viktigt? Varför?
Hur skulle du önska att kylväskan såg ut?
Vad tycker du om att det står läkemedelsnamnet och/eller företaget på väskan? Har du tänkt på det?

Hur skulle du föredra att kylväskan skulle hanteras? Hur skulle du vilja bära den?
Feedback, skulle du vilja ha en termometer eller annan typ av feedback på att väskan håller rätt temperatur? På vilket sätt? Vilken typ av information?

Vad skulle pålitlighet innebära för dig i den här produkten?
Vad skulle kvalitet innebära för dig i den här produkten?
Vad skulle flexibilitet innebära för dig i den här produkten?

Vad skulle du vara beredd att betala för att få en kylväska som håller 2-8 grader i 30 timmar?

FÖRBÄTTRINGSMÖJLIGHETER
Vad gillar du med din befintliga kylväska?
Vad gillar du inte?
Vad skulle ni vilja förbättra? Beskriv den perfekta kylväskan för dig!

ÖPPEN DISKUSSION om konkurrenters kylväskor.

APPENDIX VI. SURVEY

Survey Questions

BAKGRUND
Ålder
Kön
Nationalitet
Vilken medicin har du förskriven?
Behöver din medicin förvaras i 2-8°C?

ATT RESA
Har du upplevt att det är ett problem att resa med medicin?
- Ja, jag känner mig begränsad
- Varken eller
- Nej, inga problem

Har du någon gång rest med en kylväska för mediciner?
- Ja, flera gånger
- Ja, en gång
- Nej, men planerar att göra det
- Nej

Känner du att din medicin kylväska förvarar din medicin på ett säkert sätt?
- Ja
- Nej
- Varken eller

Hur pålitlig tycker du att din medicinkylväska är?
- 1. Inte alls pålitlig
- 2.
- 3.
- 4.
- 5. Väldigt pålitlig
- Inget svar

I vilka syften reser du främst?
- Jobbärenden
- Privata ärenden

Hur många gånger per år reser du med kyld medicin?
Hur länge tar vanligtvis resan? (enkel tur)
Hur lång brukar resan vara? (antal dagar)
Hur upplever du det vara att förbereda och packa din medicin kylväska?
- Jag upplever inga problem
- Tidskrävande
- Komplicerat sätt att packa medicinerna
- Problem att få plats med all medicin
- Svårt att veta om man stängt den ordentligt
- Svårt att veta om den är korrekt packad
- Problem att veta att medicinen inte blir för mycket kyld

Har du någon gång upplevt att medicinen tagit skada av att du rest med den?
- Ja
- Nej

Vilka transportmedel reser du vanligtvis med när du har med dig medicin kylväskan?
- Tåg
- Buss
- Flyg
- Båt
- Bil
- Cykel / Motorcykel

Har du någon gång upplevt problem när du rest med flyg?
- Ja, ofta
- Ja, ibland
- Nej

Om ja, i vilken situation har du upplevt problem?

KYLVÄSKAN
Skulle du kunna tänka dig att betala extra för en premium kylväska för din medicin?
- Ja
- Ja, i viss mån
- Nej

Hur mycket har du spenderat på din medicin kylväska?
Vad skulle du vilja förbättra med din medicin kylväska?

Övriga kommentarer

APPENDIX VII. PERSONAS

Sarah Johnson

Sarah Johnson is a young and enthusiastic businesswoman and a mother of two. Sarah and her family lives just outside of Stockholm, Sweden in a house near a lake. Sarah, who has always been an adventurous woman and travelled frequently when she was younger. The love of travelling is something she shares with her husband who she actually met on a vacation in the US. The family settled down in Sweden but is now longing for a three-week trip to the grandparents, who are living in the suburbs of Los Angeles. The trip is somewhat troublesome for Sarah, as she has not travelled that long a distance since she received her diagnosis of multiple sclerosis a few years ago and thereby worries that the medicine won't be kept cool for the entire flight and travel. The cooling is not the only thing that worries Sarah, the cooler bag for the medicine that Sarah received from her physicist looks like a cheap and unreliable product and she would rather have it packed in her own carry-on luggage so that no one can spot her illness. Nevertheless, Sarah is up for the challenge to not be restricted in her travelling by the medication. Before leaving her home, she packs the four medication packs needed with the supplied ice packs, zips the zipper and puts the bag over her shoulder. Then she stuffs her family into the car and drives of to the airport.

The security check at the airport goes smooth as Sarah shows up her passport and medication certificate. When the screening is done the family boards the flight and Sarah asks the flight attendants to put her medication in the aircraft coolers in order to be certain that they keep cool during the flight, luckily there are still space in the coolers and Sarah are permitted to put her medication there. After the flight, Sarah puts her medication into the cooler bag again, but feels a bit stressed over the fact that the ice packs seem to have lost a great deal of cooling capacity during the flight. Fortunately, the drive to her husband's parents' home is relatively short, which gives comfort but the stress is not relieved until she has packed her medication into the refrigerator at her in-laws. Even though Sarah feels great about travelling to the US, she can't help but thinking that she doesn't know that her medication have been within the recommended temperature range during the entire travel.

Juliette Anderson

Juliette Anderson is an ambitious student who has just graduated from high school. She lives in a small villa together with her parents and cat in Malmö, Sweden. After years of studies she has finally gotten a break and she is now eager to discover the world on her own. Juliette, who has been fascinated in surfing for a long time has now decided travel to Australia for a month and join a popular surfing camp in Melbourne. This is her first time travelling alone and she is a bit nervous especially since she has not travelled any long distances after receiving her diagnosis juvenile idiopathic arthritis at the age of 15. Her main concern is the short cooling time of her medical cooler bag that only guarantees cooled medication for 8 hours.

The most convenient, but rather expensive, alternative for her was to fly from Stockholm Arlanda via Bangkok to reach the final destination, Melbourne. The flight duration reaches 25 hours, which leaves her no choice but having to re-cool her medication on board. She contacted the airline company Thai Airways who said that it was okay for her to store the medication in the flight trolley where the food is kept cold. Planning the trip was very time consuming for Juliette and she felt it was slightly embarrassing to have to contact the airline company to ask for special services. She wished that there were an easier way for her to travel smoothly. At the day of the travel, Juliette packs one cooling bag with four packages of medicine and two extra packages in an other cooling bag just in case if the medication will get damaged and fills both of the cooling bags with ice packs. When she gets on board the plane the flight crew is happy to help her out with keeping her medication cooled. Even though Juliette got the support and help she needed from the flight crew she still felt a bit unsettled that the medication was out of reach during the travel.

APPENDIX VIII. LIST OF REQUIREMENTS

	Requirement	Measure	Im.	Comment
Key Requirements	Hold temperature sensitive medicines	Prototype testing	*Key*	
	Deliver 2-8 °C	Prototype testing	*Key*	In an ambient temperature of 20-25°C
	Maintain required temperature for over 24 hours	Prototype testing	*Key*	In an ambient temperature of 20-25°C
	Maximum size according to regulations of carry on luggage	560 x 450 x 250 mm	*Key*	IATA Guidelines
	Meet regulations concerning liquid medicine	Evaluation	*Key*	IATA Guidelines
	Be able to carry at least 5 doses of medicine	Prototype testing	*Key*	Travel duration of 3 weeks with 1-2 extra doses
	Cooling technique should meet the regulations for airport security and airlines	Evaluation	*Key*	IATA, TSA, SAS
Usability	Compartmentalized	Evaluation CAD model	4	
	Removeable cooling units	Evaluation CAD model	5	
	Removeable med compartment	Evaluation CAD model	2	
	Cooling units that are designed to fit commercial freezers	Evaluation CAD model	5	
	Easy to access the different compartments	Evaluation prototype	4	
	Intuitive packaging solution	Evaluation CAD model	5	
	Be able to re-cool or re-fill the cooling during the travel	Evaluation CAD model	2	
Economics	Competitive price level	Evaluation CAD model	4	Material selection
Ergonomics	Easy to transport	Evaluation prototype	4	
	Designed for 5th percentile women, 95th percentile men	Evaluation CAD model	4	
	Easy to close and open	Evaluation prototype	4	
	Light weight	Evaluation CAD model	3	Material selection
Sustainability	Volume effective	Evaluation CAD model	4	
	Food grade plastics	Evaluation CAD model	4	Material selection
Technical	Be waterresistant	Evaluation CAD model	4	Material selection
	Be impact resistant	Evaluation CAD model	4	Material selection

	Guideline	Comment
Aesthetics	Admit reliability, quality, simplicity and user friendliness	
	Express confidence, performance, flexibility, simplicity	
	Be caring, portable, encouraging	
	Overall neutral colours	Not be attentive, eye catching
	Medicine should be visible when open	Aid airport security
Brandability	Possible to brand the product towards different pharmaceutical companies.	Only if sponsored product
Feedback	Indication of remaining cooling time	
	Thermometer	
	Prediction of remaining cooling time	
Technical	Declaration of cooling units' substance(s)	Aid airport security
Usability	Stable to put on the ground or table	
	All medication equipment at the same location	E.g. needles, syringes, pens

APPENDIX IX. SWOT ANALYSIS

SUITCASE

STRENGTHS	WEAKNESSES
Easy to transport Familiar design Connection to airports Easy to pack	Limited use area Designed for airports Stationary travel pattern Double roller bags Size issues Large to store at home Diffucult to handle onboard aircraft
OPPORTUNITIES	**THREATS**
Premium bag Quality Technology	Expensive Difficult in airport aecurity May become too much of an ordinary roller bag

MESSENGER BAG

STRENGTHS	WEAKNESSES
Flexibility Anonymous Compatibility with other bags Light weight For everyone Easy to store at home No ergonomic extensions	Additional carry-on luggage
OPPORTUNITIES	**THREATS**
Customization Cheap Send home when empty	May become large Complicated feedback

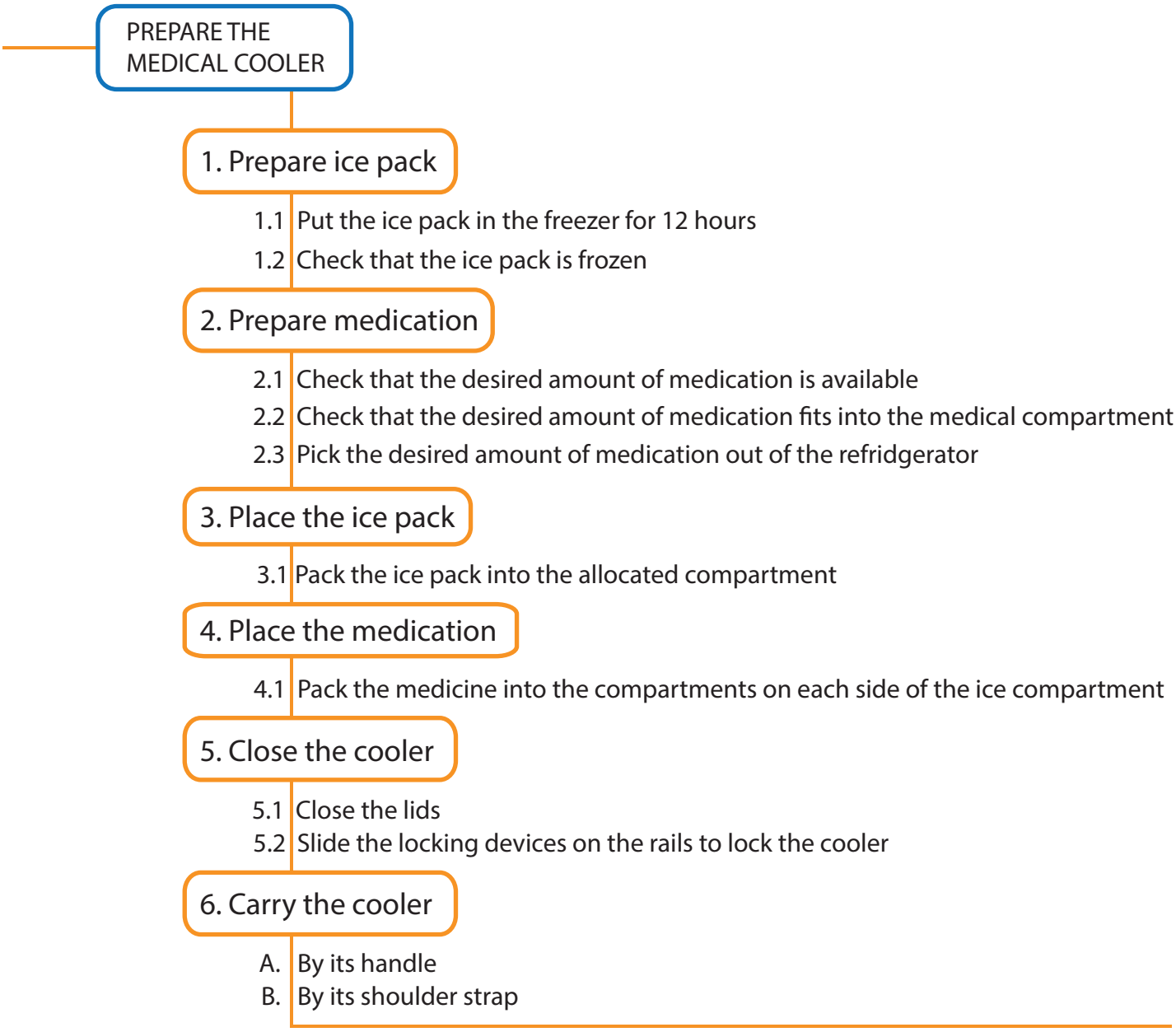
BACKPACK

STRENGTHS	WEAKNESSES
Flexibility Practical Ergonomic Active travel pattern Light weight	Complicated Packaging
OPPORTUNITIES	**THREATS**
Association to adventure and fun User friendly Unique New product category	Ergonomic demands Strange appearance Failure

DUFFEL

STRENGTHS	WEAKNESSES
For everyone Familiar design Easy to transport Versitile carrying manner Easy to modify Easy to pack Multipurpose	Is a bit of everything
OPPORTUNITIES	**THREATS**
Customisation Different sizes Cheap Easy to bring Multipurpose	May look like an ordinary thermal bag Ergonomic demands May become bulky Boring

APPENDIX X. HTA



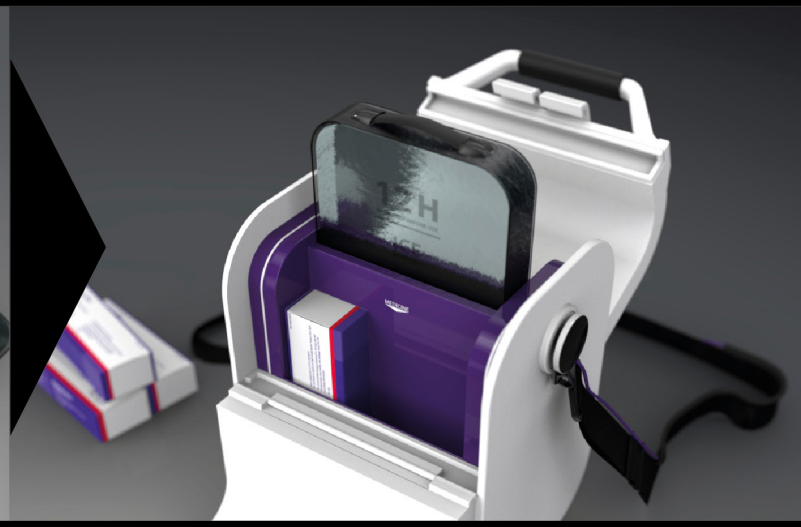
APPENDIX XI. USAGE OF AWAY

PLACE THE ICEPACK IN THE FREEZER FOR 12 HOURS.

TAKE OUT THE ICEPACK AFTER 12 HOURS
AND CHECK IF FROZEN.

PICK A DESIRED AMOUNT OF MEDICATION OUT
FROM THE REFRIDGERATOR.

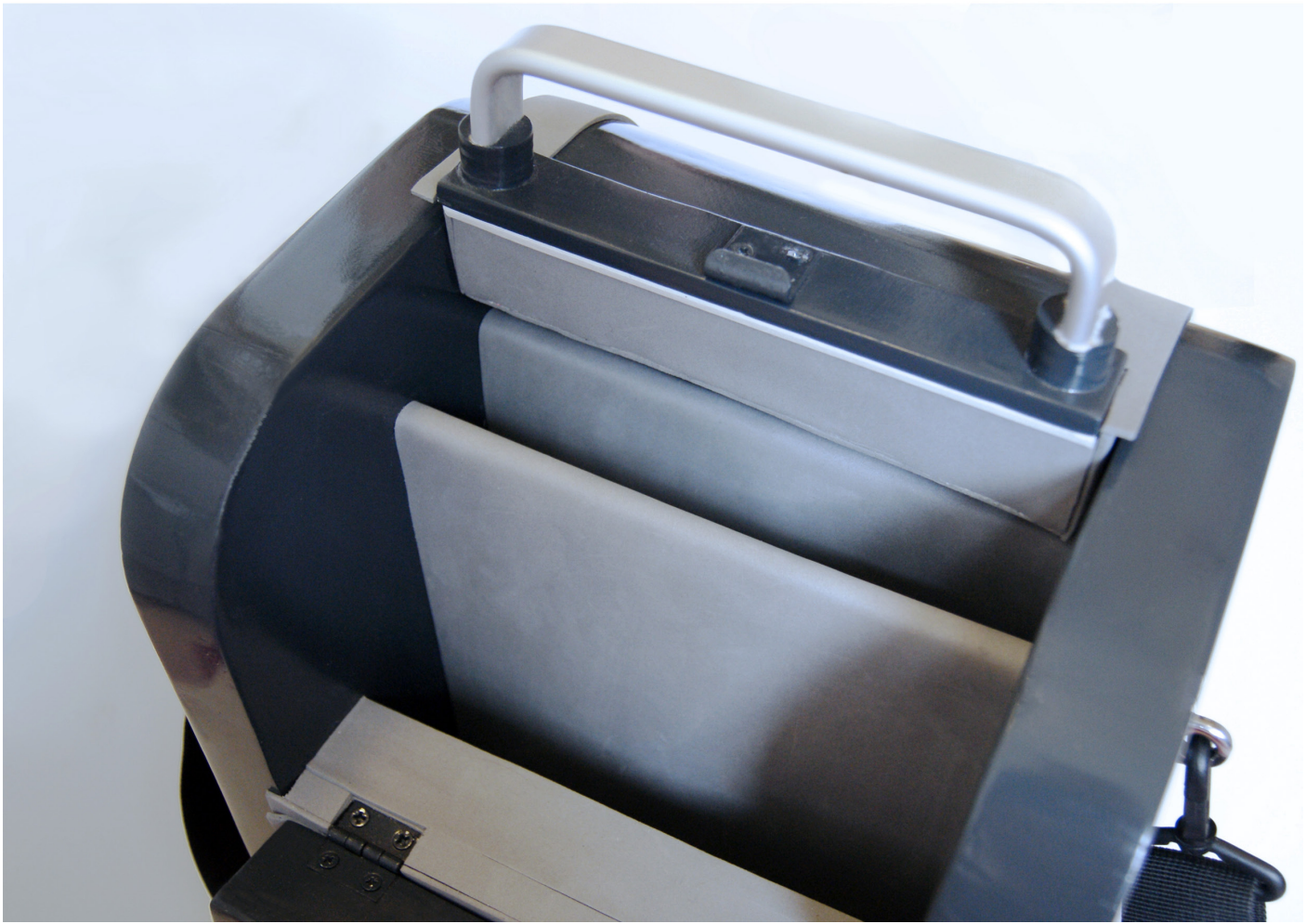
PLACE THE ICEPACK IN THE ICE COMPARTMENT AND
THE MEDICATION IN THE MEDICAL COMPARTMENT.



CLOSE THE LIDS AND SLIDE THE LOCKING DEVICES
ON THE RAILS TO THE ENDS.

READY TO USE

APPENDIX XII. THE PROTOYPE




AVONEX


AVONEX
AVONEX

APPENDIX XIII. FOCUS GROUP QUESTIONS

Evaluation Questionnaire - RENDERINGS

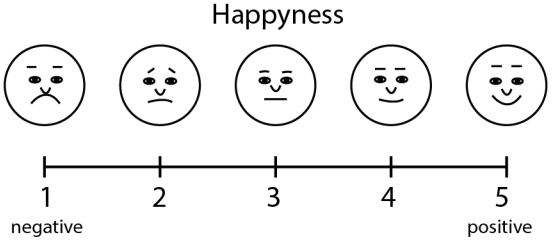
FIRST IMPRESSION

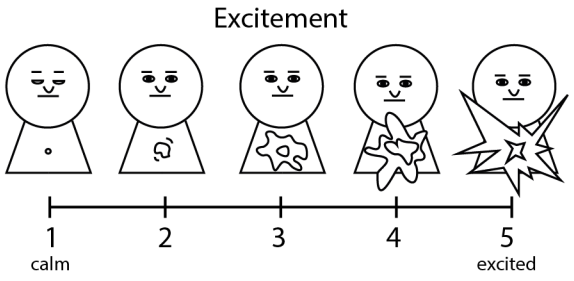
What is your first impression? _____

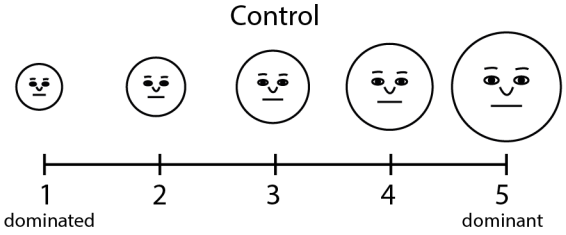
AWAY

Please rank the following aspects	1	2	3	4	5	RESULT: MEAN VALUE
Reliability	☐	☐	☐	☐	☐	4.5
Quality	☐	☐	☐	☐	☐	4.8
User Experience	☐	☐	☐	☐	☐	4.3
Anonyminity	☐	☐	☐	☐	☐	3.2
Modern	☐	☐	☐	☐	☐	4.3
Personal/Unique	☐	☐	☐	☐	☐	3.5
Caring	☐	☐	☐	☐	☐	4.2
Encouraging	☐	☐	☐	☐	☐	4.3
Flexible	☐	☐	☐	☐	☐	4
Confidence	☐	☐	☐	☐	☐	4
Fun	☐	☐	☐	☐	☐	2.7
Dimensions	☐	☐	☐	☐	☐	3.3
Aesthetics	☐	☐	☐	☐	☐	4.7
ICE PACK						
Quality	☐	☐	☐	☐	☐	4.5
Reliability	☐	☐	☐	☐	☐	4.3
Dimensions	☐	☐	☐	☐	☐	4.7
GADGET						
Usefulness	☐	☐	☐	☐	☐	4.7
Aesthetics	☐	☐	☐	☐	☐	4.2

EMOTIONS







RESULT: MEAN VALUE

4.2

3.7

4

COMMENTS

Evaluation Questionnaire - PROTOTYPE

USE SCENARIO

Please rank the following aspects

The cooler..	Totally Disagree 1	2	3	4	Totally Agree 5	RESULT: MEAN VALUE
.. is easy to carry	☐	☐	☐	☐	☐	3.3
.. is easy to open	☐	☐	☐	☐	☐	4.5
.. is comfortable to use	☐	☐	☐	☐	☐	3.8
.. has intuituve design	☐	☐	☐	☐	☐	4.8
.. has a neat packaging	☐	☐	☐	☐	☐	4.8
.. is time consuming to pack	☐	☐	☐	☐	☐	2.2
.. is simple to use	☐	☐	☐	☐	☐	4.3
.. feels reliable	☐	☐	☐	☐	☐	4
.. feels durable	☐	☐	☐	☐	☐	4.3
.. feels qualitative	☐	☐	☐	☐	☐	4.7
.. feels embarrasing to use	☐	☐	☐	☐	☐	2.3
.. feels personal	☐	☐	☐	☐	☐	3.2
.. fits into the travelling scenario	☐	☐	☐	☐	☐	4
.. enables an easy security screening	☐	☐	☐	☐	☐	4.3

Agree/Disagree

I would..	Agree	Disagree
.. use the cooler when I travel	☐ 6	☐ 0
.. feel comfortable to use the cooler when I travel	☐ 5	☐ 1
.. feel that the medicine were transported securely in the cooler	☐ 5	☐ 1
.. trust the cooler to be cold during the entire trip	☐ 5	☐ 1
.. be willing to buy the cooler (1500 SEK)	☐ 6	☐ 0
.. prefer if the cooler was sponsored (Free)	☐ 3	☐ 3
.. prefer if the cooler could be used in other contexts	☐ 2	☐ 4
.. prefer to use this cooler instead of other products on the market	☐ 6	☐ 0

APPENDIX XIV. ENVIRONMENTAL IMPACT

INTERIOR

Carbon Footprint

Material:	4.3 kg CO_2
Manufacturing:	2.5 kg CO_2
Transportation:	0.046 kg CO_2
End of Life:	0.984 kg CO_2

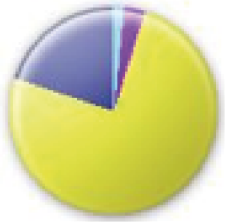
7.8 kg CO_2

Total Energy Consumed

Material:	100 MJ
Manufacturing:	25 MJ
Transportation:	0.575 MJ
End of Life:	0.753 MJ

130 MJ

Air Acidification



Material:	9.3E-3 kg SO_2
Manufacturing:	0.035 kg SO_2
Transportation:	1.5E-3 kg SO_2
End of Life:	7.1E-4 kg SO_2

0.047 kg SO_2

Water Eutrophication

Material:	1.6E-3 kg PO_4
Manufacturing:	1.4E-3 kg PO_4
Transportation:	1.4E-4 kg PO_4
End of Life:	4.8E-4 kg PO_4

3.6E-3 kg PO_4

BOTTOM

Carbon Footprint

Material:	12 kg CO_2
Manufacturing:	7.1 kg CO_2
Transportation:	0.132 kg CO_2
End of Life:	2.8 kg CO_2

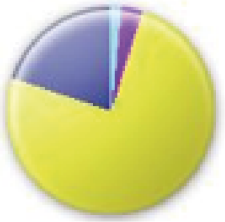
22 kg CO_2

Total Energy Consumed

Material:	300 MJ
Manufacturing:	71 MJ
Transportation:	1.6 MJ
End of Life:	2.2 MJ

370 MJ

Air Acidification



Material:	0.026 kg SO_2
Manufacturing:	0.100 kg SO_2
Transportation:	4.4E-3 kg SO_2
End of Life:	2.0E-3 kg SO_2

0.133 kg SO_2

Water Eutrophication

Material:	4.6E-3 kg PO_4
Manufacturing:	3.9E-3 kg PO_4
Transportation:	4.1E-4 kg PO_4
End of Life:	1.4E-3 kg PO_4

0.010 kg PO_4

TOP FRONT

Carbon Footprint

Material:	1.3 kg CO_2
Manufacturing:	0.767 kg CO_2
Transportation:	0.029 kg CO_2
End of Life:	0.398 kg CO_2

2.5 kg CO_2

Total Energy Consumed

Material:	32 MJ
Manufacturing:	7.6 MJ
Transportation:	0.395 MJ
End of Life:	0.310 MJ

40 MJ

Air Acidification

Material:	2.9E-3 kg SO_2
Manufacturing:	0.011 kg SO_2
Transportation:	1.5E-4 kg SO_2
End of Life:	3.2E-4 kg SO_2

0.014 kg SO_2

Water Eutrophication

Material:	5.0E-4 kg PO_4
Manufacturing:	4.2E-4 kg PO_4
Transportation:	3.0E-5 kg PO_4
End of Life:	7.6E-5 kg PO_4

1.0E-3 kg PO_4

TOP WITH CLASP

Carbon Footprint

Material:	1.6 kg CO_2
Manufacturing:	0.948 kg CO_2
Transportation:	0.036 kg CO_2
End of Life:	0.493 kg CO_2

3.1 kg CO_2

Total Energy Consumed

Material:	39 MJ
Manufacturing:	9.4 MJ
Transportation:	0.488 MJ
End of Life:	0.383 MJ

50 MJ

Air Acidification

Material:	3.5E-3 kg SO_2
Manufacturing:	0.013 kg SO_2
Transportation:	1.8E-4 kg SO_2
End of Life:	4.0E-4 kg SO_2

0.018 kg SO_2

Water Eutrophication

Material:	6.2E-4 kg PO_4
Manufacturing:	5.2E-4 kg PO_4
Transportation:	3.7E-5 kg PO_4
End of Life:	9.4E-5 kg PO_4

1.3E-3 kg PO_4

LOCK

Carbon Footprint

Material:	0.107 kg CO_2
Manufacturing:	0.062 kg CO_2
Transportation:	2.4E-3 kg CO_2
End of Life:	0.032 kg CO_2

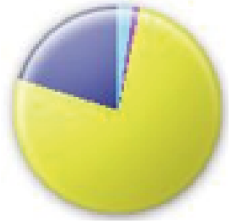
0.204 kg CO_2

Total Energy Consumed

Material:	2.6 MJ
Manufacturing:	0.621 MJ
Transportation:	0.032 MJ
End of Life:	0.025 MJ

3.3 MJ

Air Acidification



Material:	2.3E-4 kg SO_2
Manufacturing:	8.8E-4 kg SO_2
Transportation:	1.2E-5 kg SO_2
End of Life:	2.6E-5 kg SO_2

1.1E-3 kg SO_2

Water Eutrophication

Material:	4.0E-5 kg PO_4
Manufacturing:	3.4E-5 kg PO_4
Transportation:	2.4E-6 kg PO_4
End of Life:	6.2E-6 kg PO_4

8.3E-5 kg PO_4

ICE

Carbon Footprint

Material:	0.595 kg CO_2
Manufacturing:	0.00 kg CO_2
Transportation:	0.013 kg CO_2
End of Life:	0.184 kg CO_2

0.793 kg CO_2

Total Energy Consumed

Material:	14 MJ
Manufacturing:	0.00 MJ
Transportation:	0.183 MJ
End of Life:	0.143 MJ

15 MJ

Air Acidification

Material:	1.3E-3 kg SO_2
Manufacturing:	0.00 kg SO_2
Transportation:	6.8E-5 kg SO_2
End of Life:	1.5E-4 kg SO_2

1.5E-3 kg SO_2

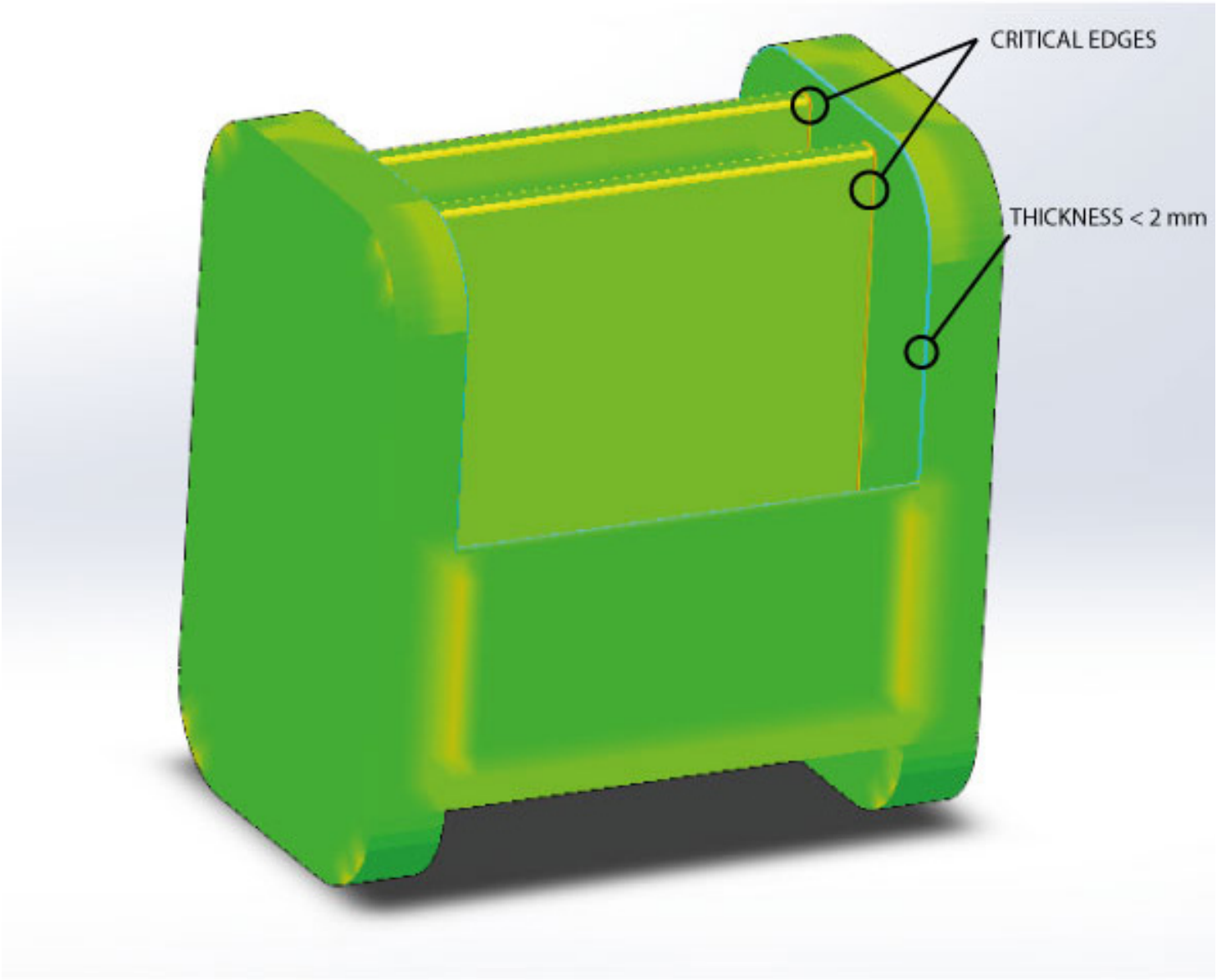
Water Eutrophication

Material:	2.3E-4 kg PO_4
Manufacturing:	0.00 kg PO_4
Transportation:	1.4E-5 kg PO_4
End of Life:	3.5E-5 kg PO_4

2.7E-4 kg PO_4

APPENDIX XV. DESIGN EVALUATION

EVALUATION 1.
INTERIOR



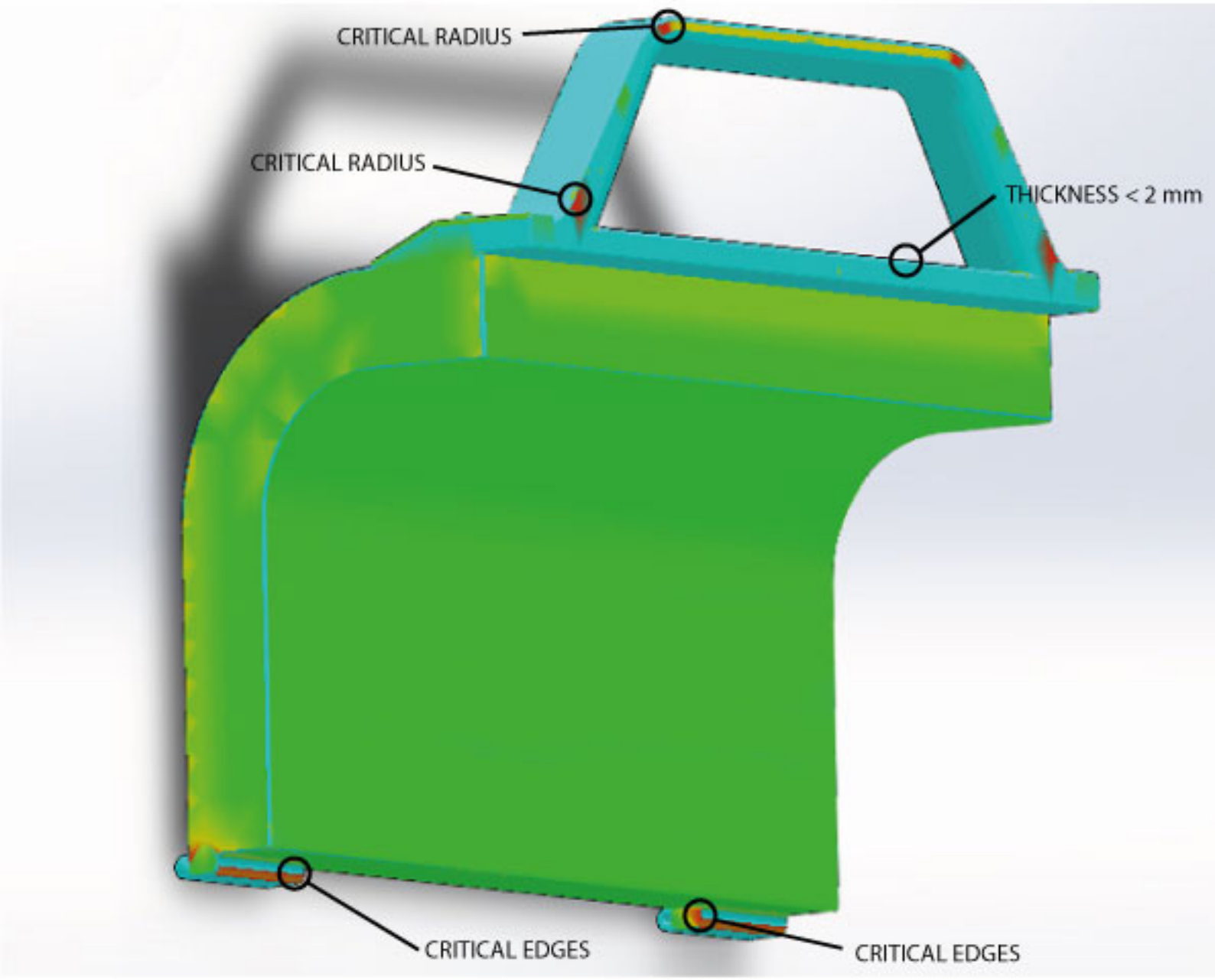
Thickness
< 2 mm

> 3.5 mm

Thickness range	Number of faces	% of analyzed area
2mm to 2.5mm	0	0.08%
2.5mm to 3mm	16	2.48%
3mm to 3.5mm	54	96.70%
3.5mm to 4mm	54	0.45%

Number of critical features: 9

EVALUATION 2.
EXTERIOR LID WITH HANDLE



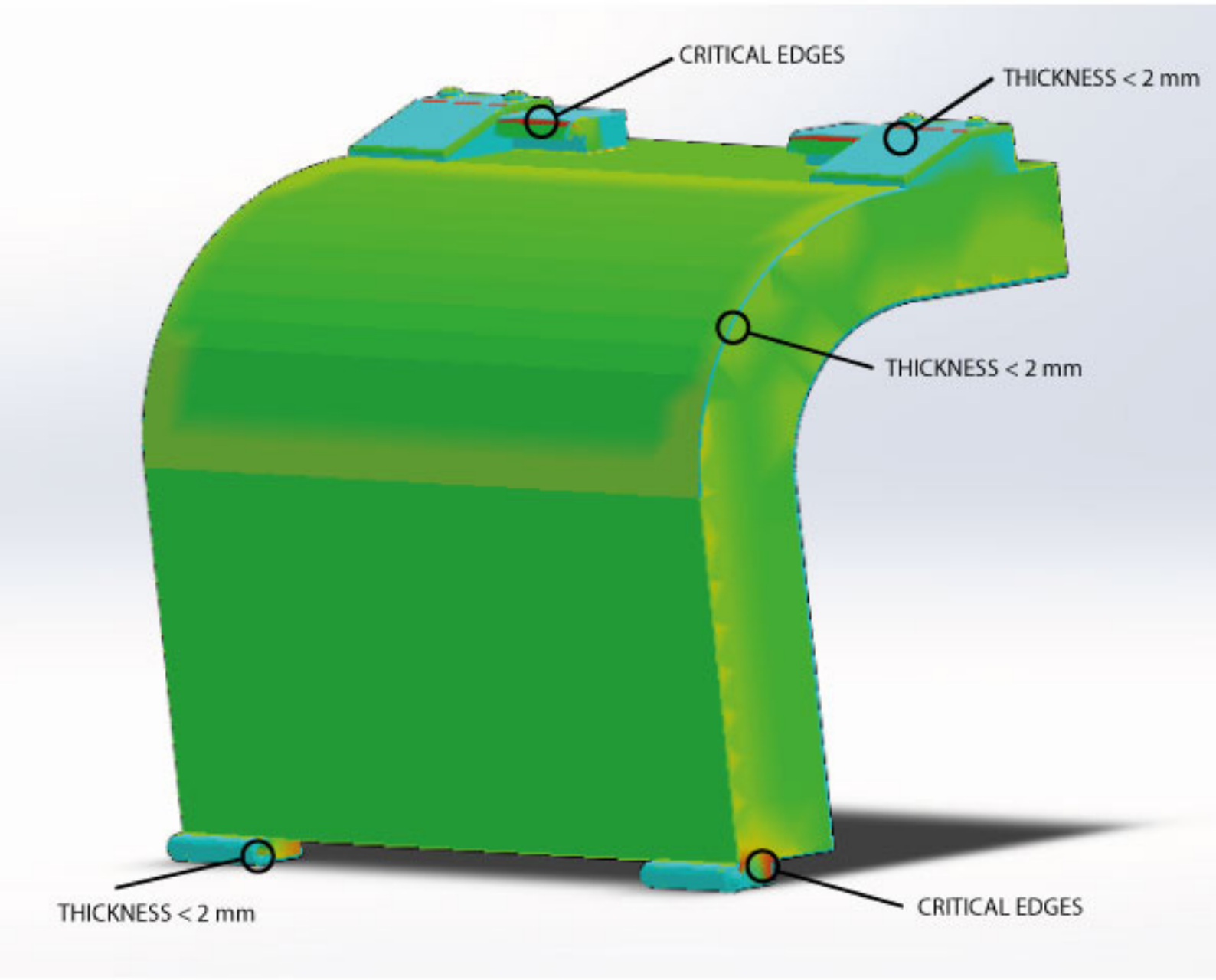
Thickness
< 2 mm

> 3.5 mm

Thickness range	Number of faces	% of analyzed area
2mm to 2.5mm	3	0.05%
2.5mm to 3mm	9	20.22%
3mm to 3.5mm	50	34.02%
3.5mm to 4mm	23	0.17%

Number of critical features: 24

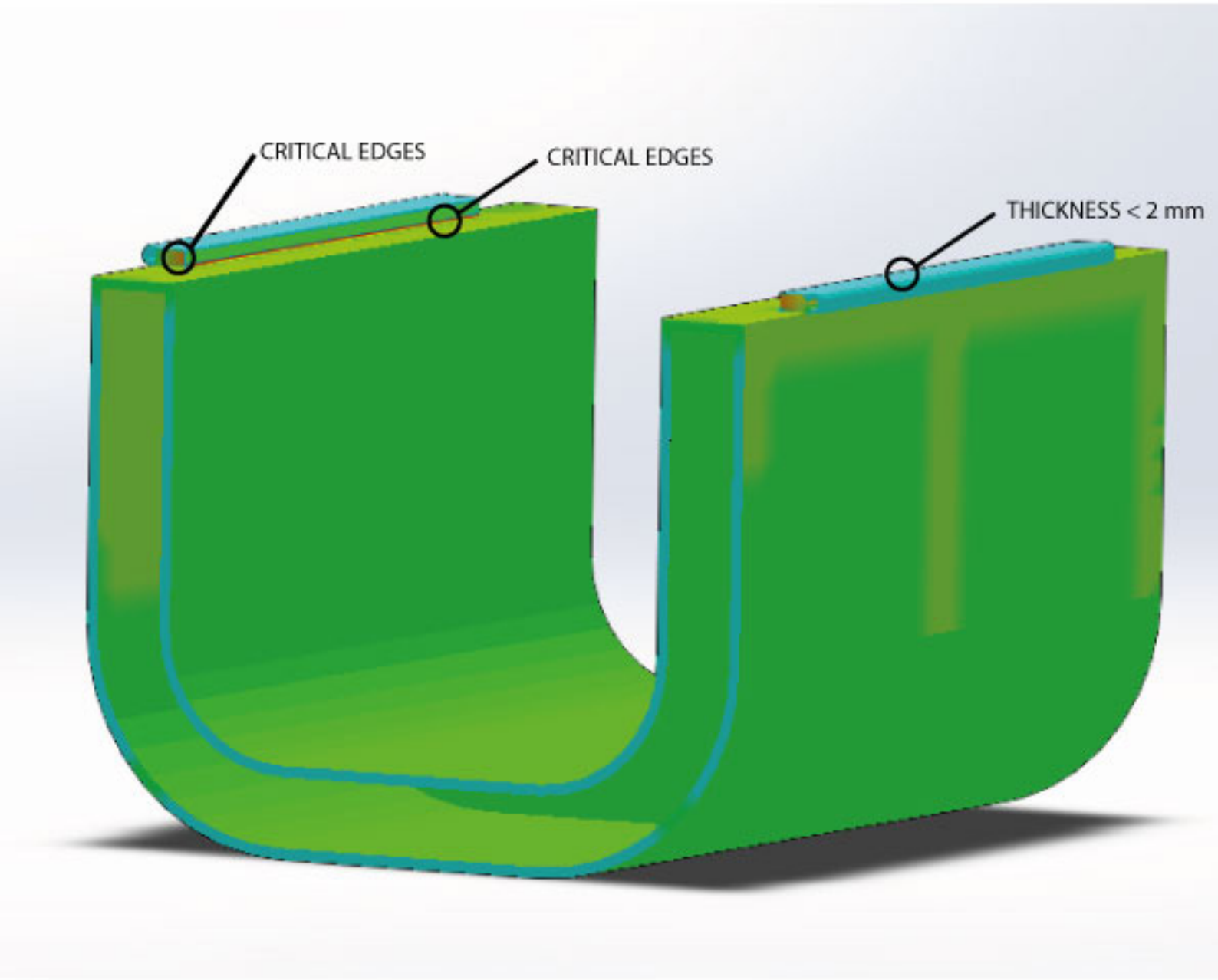
EVALUATION 3.
EXTERIOR LID



Thickness range	Number of faces	% of analyzed area
2mm to 2.5mm	4	0.06%
2.5mm to 3mm	6	11.05%
3mm to 3.5mm	56	83.09%
3.5mm to 4mm	22	0.20%

Number of critical features: 26

EVALUATION 4.
EXTERIOR BOTTOM



Thickness
> 2 mm

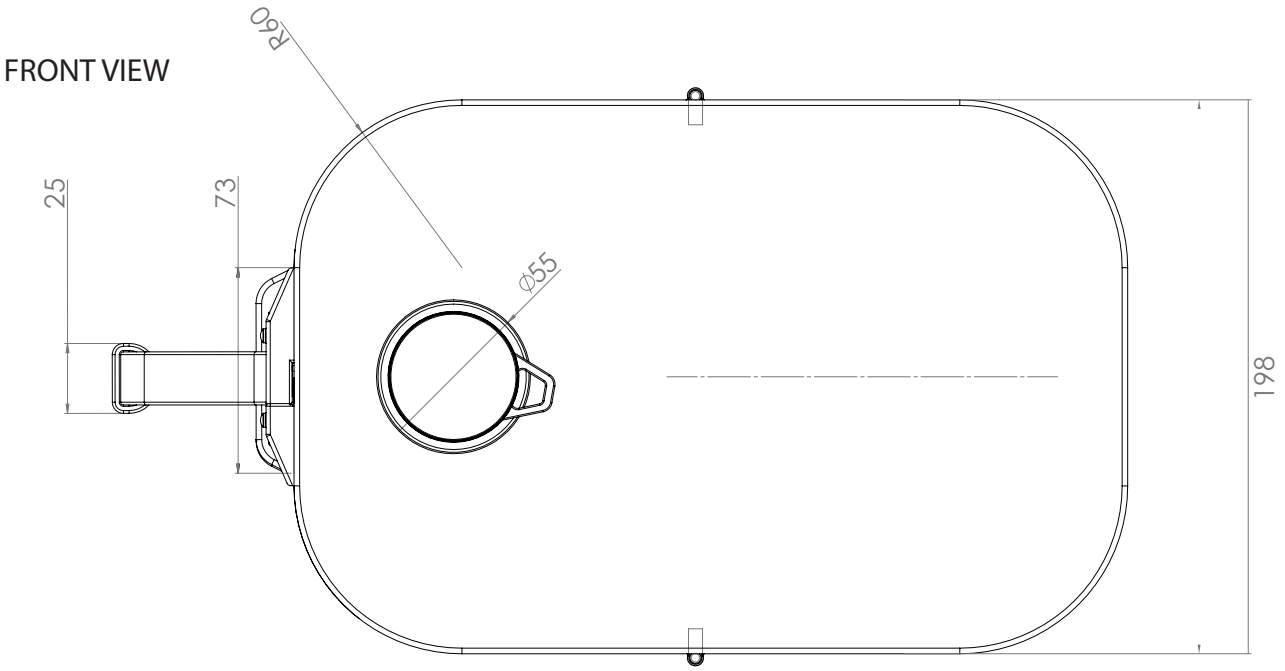
< 3.5 mm

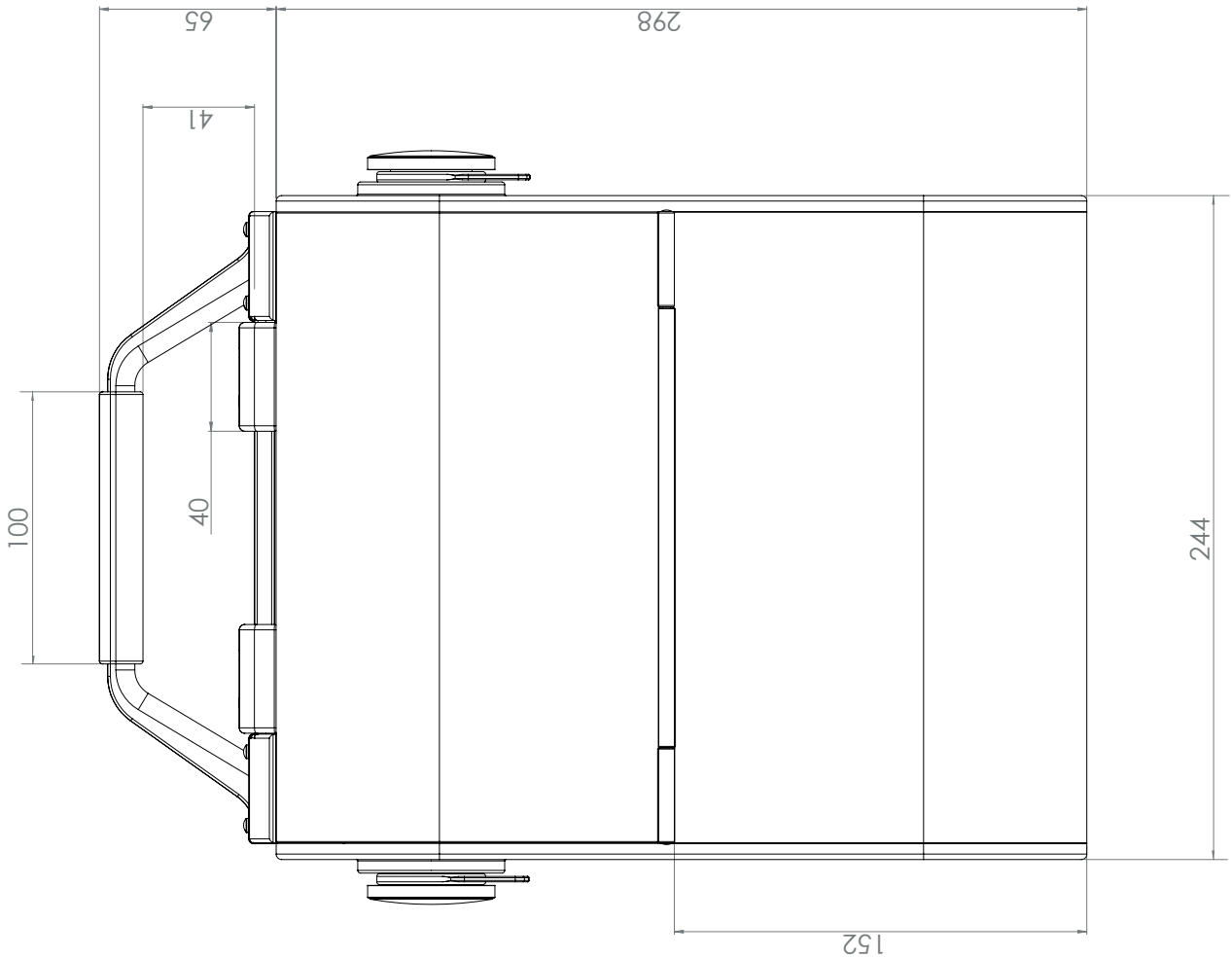
Thickness range	Number of faces	% of analyzed area
2mm to 2.5mm	4	0.00%
2.5mm to 3mm	6	32.40%
3mm to 3.5mm	56	63.43%
3.5mm to 4mm	22	0.19%

Number of critical features: 5

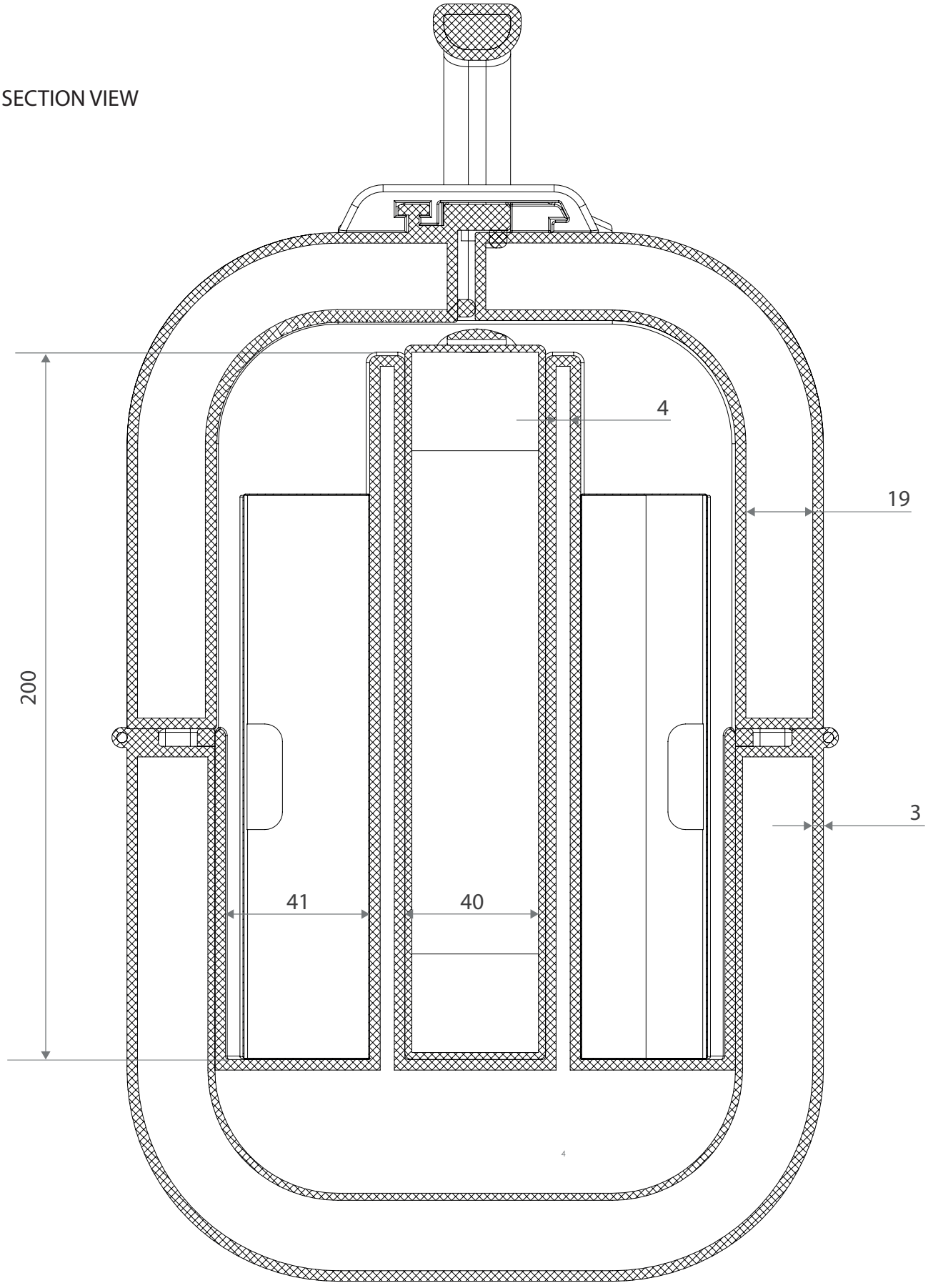
APPENDIX XVI. BLUEPRINTS

FRONT VIEW





SECTION VIEW



APPENDIX XVII. FULFILMENT OF REQUIREMENTS

	Requirement	Measure	Im.	Fulfilment
Key Requirements	Hold temperature sensitive medicines	Prototype testing	*Key*	Fulfilled
	Deliver 2-8 °C	Prototype testing	*Key*	Fulfilled
	Maintain required temperature for over 24 hours	Prototype testing	*Key*	Possible to Fulfill
	Maximum size according to regulations of carry on luggage	560 x 450 x 250 mm	*Key*	Fulfilled
	Meet regulations concerning liquid medicine	Evaluation	*Key*	Fulfilled
	Be able to carry at least 5 doses of medicine	Prototype testing	*Key*	Fulfilled
	Cooling technique should meet the regulations for airport security and airlines	Evaluation	*Key*	Fulfilled
Usability	Compartmentalized	Evaluation CAD model	4	Fulfilled
	Removeable cooling units	Evaluation CAD model	5	Fulfilled
	Removeable med compartment	Evaluation CAD model	2	Possible to Fulfill
	Cooling units that are designed to fit commercial freezers	Evaluation CAD model	5	Fulfilled
	Easy to access the different compartments	Evaluation prototype	4	Fulfilled
	Intuitive packaging solution	Evaluation CAD model	5	Fulfilled
	Be able to re-cool or re-fill the cooling during the travel	Evaluation CAD model	2	Possible to Fulfill
Economics	Competitive price level	Evaluation CAD model	4	Possible to Fulfill
Ergonomics	Easy to transport	Evaluation prototype	4	Fulfilled
	Designed for 5th percentile women, 95th percentile men	Evaluation CAD model	4	Fulfilled
	Easy to close and open	Evaluation prototype	4	Fulfilled
	Light weight	Evaluation CAD model	3	Fulfilled
Sustainability	Volume effective	Evaluation CAD model	4	Fulfilled
	Food grade plastics	Evaluation CAD model	4	Fulfilled
Technical	Be waterresistant	Evaluation CAD model	4	Fulfilled
	Be impact resistant	Evaluation CAD model	4	Fulfilled

	Guideline	Fulfilment
Aesthetics	Admit reliability, quality, simplicity and user friendliness	Fulfilled
	Express confidence, performance, flexibility, simplicity	Fulfilled
	Be caring, portable, encouraging	Fulfilled
	Overall neutral colours	Fulfilled
	Medicine should be visible when open	Fulfilled
Brandability	Possible to brand the product towards different pharmaceutical companies.	Possible to Fulfill
Feedback	Indication of remaining cooling time	Fulfilled
	Thermometer	Fulfilled
	Prediction of remaining cooling time	Fulfilled
Technical	Declaration of cooling units' substance(s)	Fulfilled
Usability	Stable to put on the ground or table	Fulfilled
	All medication equipment at the same location	Fulfilled