Bio-based Clothes Covers for a High-end Clothing Brand

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Bio-based Clothes Covers for a High-end Clothing Brand

by

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Biobaserade klädskydd för ett exklusivt klädmärke

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Abstract

There is a growing interest in using plastics from renewable resources and other bio-based materials to replace conventional oil-based plastics. This report presents the development of a new bio-based clothes cover for a high-end clothing brand.

The project was carried out as a Master’s Thesis project in Industrial Design Engineering at the research institute Innventia AB commissioned by the clothing brand Tiger of Sweden.

The project’s development process was based on The Mechanical Design Process by David G. Ullman. A web-based survey, an idea generation workshop and a perception study were performed as a basis for the investigation.

The new clothes cover is intended for hanging clothes, primarily suits. The new clothes cover should be effectively managed in the transport chain and be aesthetically appealing. Additionally, it should add value by being used by the end-users as a transport bag when buying a suit. The study had a large focus on the selection of a suitable bio-based material for the application.

The project resulted in two product concepts: one to be used from production to retail and from the store to the customer’s home and the other primarily to be used as a transport cover. The first concept, Concept 1, is a foldable clothes cover made in bio-based polyethylene. The product concept fulfills the requirements within the transport chain and can also be carried as a garment bag. Concept 2 is a premium transport
cover also made in bio-based polyethylene. The cover has a stiff exclusive look and is closed at the bottom with a resealable zip-lock.

Bio-based polyethylene was selected because it possesses the most suitable properties for this demanding application and is nearest to a commercially implementable solution. The flexibility, water barrier and great manufacturability of polyethylene outperformed the other bio-based competitors among starch-based plastics, polylactic acid and paper materials.

The project was delimited to be adapted to the prevailing methods Tiger of Sweden was using in their transport chain and finally, cost and profitability studies were not included.
Sammanfattning


Utvecklingsprocessen i projektet baserades på boken The Mechanical Design Process av David G. Ullman. En webbaserad enkätundersökning, en idégenereringsworkshop och en perceptionsstudie låg till grund för studien.


Biobaserad polyeten valdes för att den har lämpligast egenskaper för den här applikationen samt att den är kommersiellt realiserbar. Biobaserad polyeten är flexibelt,
har god vätskebarriär och producerbarhet vilket gör den oöverträffad gentemot sina biobaserade konkurrenter, så som stärkelsebaserad plast, polylaktid (PLA) och papper.

Projektet var avgränsat till att slutkonceptet skulle kunna hanteras inom transportkedjan med Tiger of Swedens rådande metoder. Ingen kostnadsanalys eller lönsamhetsstudie var inkluderad i projektet.
Acknowledgement

This report presents a Master Thesis project (30 ECTS) conducted at the Department of Mechanical Engineering in Industrial Design at the Royal Institute of Technology (KTH), Stockholm. The project was carried out at the research institute Innventia AB on behalf of the clothing company and brand Tiger of Sweden.

First of all I want to thank my supervisors MSc. Karin Edström and Dr. Marie-Claude Béland at Innventia AB for all the support, shared knowledge and discussions during the project. I also want to thank Product Director Tina Broman at Tiger of Sweden for involving me in this project. Tina Broman has provided me with necessary information to carry out the project, as well as contributed with valuable ideas and support. Furthermore, I want to thank my supervisor Anna Hedlund Åström at KTH for the supervisory meetings and guidance throughout the project.

Additionally, I want to thank all the employees at Innventia AB that have provided me with technical support, material knowledge and discussions. Finally, I want to thank my family, girlfriend and friends for supporting me during this project.

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Abstract

Sammanfattning

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1. Introduction

This chapter presents the background and the problem description, purpose and goals of the project as well as delimitations.

1.1 Background and problem description

The world’s annual production of plastics is 300 million tons and the plastic industry has been growing continuously for more than 50 years. The largest sector for the plastic industry is packaging applications, which stands for 40 % of the plastic industry. (PlasticsEurope, 2014) Most of the plastics are produced from the non-renewable resource crude oil. However, there are other opportunities; with existing technology it is possible to produce plastics from renewable resources derived from the biomass. The biomass consists of non-fossilized organic materials originating from plants, animals or micro-organisms (Kabasci, 2014). Other renewable materials growing in use are bio-composites, which are composite materials with biological origin (Fowler et al., 2006). The usage of bio-based materials saves fossil resources and reduces the carbon footprint since the plants capture carbon during their growth process (European Bioplastics, 2015).

The purpose of this project was to develop a new premium clothes cover in a bio-based material for the high-end clothing brand Tiger of Sweden. Tiger of Sweden is an international designer brand founded 1903 in Uddevalla (IC Group, 2015). The company handles large quantities of clothes through their value chain. The clothes are mainly transported hanging, from production to retail. During transport the garments are covered in plastic to avoid dirt and damage. This cover is currently made from an oil-based plastic. Upon request from Tiger of Sweden a new clothes cover should be designed in a sustainable material which also communicates the quality Tiger of Sweden stands for.

The new clothes cover should be sustainable, effectively managed and protect the garment from dirt and damage during transport. Additionally, the cover should have an exclusive look, which will allow the clothes covers to be proudly shown for external purchasers and customers when clothes are delivered to the stores. The current plastic cover (see Figure 1.1) is for single use and is discarded when it comes to the store. The new clothes cover should add value by also being used by the end-user as a transport bag after having bought a suit.
1.2 Objectives

The main objective of the project was to develop a product concept and a proof-of-concept demonstrator for the new clothes cover which should be partially or entirely bio-based. Following research questions were meant to be answered:

- What requirements need to be fulfilled to develop a bio-based clothes cover for Tiger of Sweden?
- What materials satisfy these requirements?
- How could a clothes cover be designed to fulfil these requirements?

The main steps of the project were:

- Identify Tiger of Sweden’s requirements for a new clothes cover.
- Identify customers’ requirements for a new clothes cover.
- Develop engineering specifications for the product.
- Investigate possibilities and limitations with different bio-based materials for this application.
- Generate various concepts for a new clothes cover.
- Develop a final product concept.
- Create visual images and a proof-of-concept demonstrator of the final concept.
1.3 Delimitations

The project was delimited to investigate solutions for shorter exclusive hanging garments such as suits, blazers and jackets. Skirts, dresses and folded garments were excluded.

The new product concept was meant to work with existing technologies used at production, warehouses and stores. In other words, the cover should more or less be directly interchangeable with the existing clothes cover.

Detailed construction and manufacture processes were not meant to be investigated, since the manufacturers’ have a greater knowledge of such construction and its’ processes.

Finally, it was not included in the project to conduct a cost analysis, although cost approximations were done in order to ensure that material and production costs for the new clothes cover would stay within a reasonable cost frame.
2. Frame-of-Reference

This chapter will describe the theoretical framework of the project. A large part of the project was to investigate different bio-based materials for clothes covers; hence the following sections will be about bio-based plastics and other bio-based materials.

2.1 Bio-based plastics

Bio-based plastics are polymers produced completely or partly by biological materials derived from the biomass (Vert et al., 2012); including plants, animals or microorganisms. Bio-based plastics should not be confused with the term bio-degradable plastics. According to Kabasci (2014) bio-degradable plastics are polymers that can be degraded by micro-organisms in composting or anaerobic digestion processes. He mentions that this characteristic has to do with the molecular structure of the polymer, not the origin. Hence, both fossil-based and bio-based plastics could possess degradability (Kabasci, 2014). Bio-degradable polymers can also be biocompatible, which means that the material can coexist with tissue in the human body (Mitrus, Wojtowicz & Moscicki, 2009).

Mitrus, Wojtowicz & Moscicki (2009) state that bio-based polymers can be extracted in three ways: from natural polymers, by polymerization of bio-based monomers and from microorganisms or genetically transformed bacteria. Examples of bio-based plastics extracted from natural polymers are starch and cellulose. Bio-based plastics made from polymerized monomers are Polylactic Acid (PLA) (Mitrus, Wojtowicz & Moscicki, 2009) and bio-based Polyethylene. No polymers from microorganisms were studied in this work.

The following sections will present four classes of bio-based plastics examined in this project.

2.1.1 Starch-based plastics

Starch is a carbohydrate used for energy storage in plants. The most commercially available starch is made from either corn, potato or wheat (Šprajcar, Horvat & Kržan, 2012). Starch is composed of two types of polysaccharides: amylose and amylopectin. The ratio of the polysaccharides differs, but normally it is between 70-85% amylpectin and 15-30% amylose (Murali et al., 2012).

Thermoplastic starch (TPS) can be made by destructing it with energy and heat (Šprajcar, Horvat & Kržan, 2012) in the presence of plasticizers such as water, glycerol or sorbitol (Mitrus, 2009; Murali et al., 2013). TPS can be processed using different methods, such as extrusion, injection molding and compression molding (Mitrus, 2009; Murali et al., 2013).
Murali et al. (2013) mention that thermoplastic starch could be used alone, but in its pure form it is very sensitive to moisture. Consequently, TPS is often blended with other polymers. Murali et al. (2013) state that the moisture sensitivity limits the usefulness of TPS in humid areas. TPS produced with only water as a plasticizer becomes very brittle, therefore other plasticizers such as glycerol and sorbitol are used (Mitrus, 2009). According to Mitrus (2009) one of the major drawbacks is the brittleness of starch-based materials.

Šprajcar, Horvat & Kržan (2012) claim that TPS is one of the best polymers for short term use because of its’ good biodegradation properties. Further they mention that thermoplastic starches are used in many different areas, such as shopping bags, bags for bio-waste storage, food packaging and hygiene products. The good ventilation is an advantage with TPS when storing food (Šprajcar, Horvat & Kržan, 2012).

2.1.2 Cellulose-based plastics

Cellulose is the world’s most abundant polymer. Cellulose is a carbohydrate (Šprajcar, Horvat & Kržan, 2012), but in contrast to starch it is a structural polysaccharide used as a structural component in plant cells (Murali et al., 2012).

The most common sources for cellulose are wood and cotton (Šprajcar, Horvat & Kržan, 2012). Cellulose is used in paper and cardboard production, but also in plastics. According to Šprajcar, Horvat & Kržan (2012) the first industrial polymers were made from cellulose, namely Celluloid™ or Cellophane™. The plastic producer Innova films has created a certified bio-degradable cellulose film named Natureflex™. Natureflex™ is based on 90-99% renewable content, has a good gas barrier and optical properties and can be used for different packaging applications (Innovia Films, 2015). It is a relatively crunchy film, similar to traditional cellophane.

Cellulose fibres can also be mixed with biopolymers, creating bio-based composites, which will be further described in section 2.2.

2.1.3 Polylactic Acid

Polylactic Acid (PLA) is a biodegradable aliphatic polyester, which is one of the first polymers produced from renewable resources on an industrial scale. (Šprajcar, Horvat & Kržan, 2012)

PLA is made from plants such as sugarcane, potatoes, corn and tapioca (Voevodina & Kržan, 2013). The production process of PLA can be described as: fermentation of sugar and starch to make polylactic acid, production of the monomer lactide in order to make the polymerization into PLA (Voevodina & Kržan, 2013).
Halász, Hosakun & Csóka (2015) state that PLA has great optical properties, chemical resistance and good mechanical and thermal properties. However, PLA has high vapour and gas permeability, which makes it sensitive to long exposure of moisture (Halász, Hosakun & Csóka, 2015); it is especially sensitive to moisture in warmer humid climates. Pure PLA is very brittle and PLA as a packaging material often has a crispy character.

PLA is biodegradable, biocompatible and bioresorbable which makes it possible to degrade in industrial composting and use in medical applications (Murali et al., 2012; Voevodina & Kržan, 2013) PLA can also be blended with other polymers in order to make them biodegradable.

Today PLA is a widely available plastic and comparable in price with other classical plastics (Murali et al., 2012). PLA is used for many different applications, such as packaging, textiles and biomedical applications (Bordes, Pollet, Avérous, cited in Murali et al., 2009)

2.1.4 Bio-based Polyolefin

Polyolefins are the largest group of thermoplastics and are polymers made from simple olefins such as ethylene and propylene (UL Prospector, 2015). The most popular polyolefins are Polyethylene (PE) and Polypropylene (PP). PE and PP are usually made from petroleum, but can also be produced from renewable resources. In 2010, the Brazilian company Braskem launched a plant producing bio-based polyethylene from sugarcane bioethanol (Mülhaupt, 2013). Braskem has not yet started to produce bio-based Polypropylene, but claims they will launch it soon (Braskem, 2015).

Bio-based Polyethylene is obtained by cleaning and crushing sugarcanes into sugarcane juice. The juice is fermented into ethanol and further dehydrated to ethylene which is polymerized to Polyethylene (Šprajcar, Horvat & Kržan, 2012).

Bio-based Polyethylene has identical properties as its petroleum-based counterpart. Polyethylene is a versatile material often classified by density. The most common types are Low Density PE (LDPE), Linear Low Density PE (LLDPE) and High Density PE (HDPE). According to Emblem (2012) LDPE and LLDPE are flexible, with good elongation before breakage. They also have good water barrier and optical properties. HDPE is rigid, opaque and has better barrier properties than LDPE (Emblem, 2012). Drawbacks with PE are that it is difficult to bond, has a high thermal expansion and low strength/stiffness (UL Prospector, 2015). Bio-based Polyethylene is not biodegradable.

Mülhaupt (2013) claims that Polyethylene is superior to all bio-based plastics, because of its recycling, energy- and resource effectiveness, attractive cost and great performance.
2.2 Other bio-based materials

In this section other bio-based materials used for packaging applications will be presented. The material groups discussed are paper materials, bio-based composites and nonwovens.

2.2.1 Paper materials

Paper and paperboard are compressed sheets made from plant fibres. Riley (2012) mentions that it is commonly made from trees, but also from linen, sugar cane, cotton or cereal plants. Further he states that paper and paperboard are the most common packaging raw material.

The desired fibres for paper production are cellulosic fibres, which are attached in the wood with a stiff material called lignin. Paper is produced by separating fibres from the wood in a process called pulping (Chamberlain & Kirwan, 2012). Virgin paper pulp can be made mainly from two methods (or a combination of them): mechanical pulping or chemical pulping (Chamberlain & Kirwan, 2012; Riley, 2012). According to Riley (2012) mechanical pulping is the fastest and cheapest method; however it produces weaker paper such as newspaper. Further, he mentions that chemical pulping produces a stronger paper, which can be bleached if white paper is required. Recycled paper can be deinked and turned into pulp by using a hydropulper (Riley, 2012), which simplified is a water-filled container with a rotating blade in the bottom turning the paper into pulp.

Paper is classified by grams per square meter, grammage (g/m²) (Chamberlain & Kirwan, 2012; Riley, 2012). Paper is defined by ISO as “paperboard” if it is over 225 g/m² (Chamberlain & Kirwan, 2012). Further they mention that the appearance, mechanical properties depend on the fibre content and which type of fibres used, among other things.

Paper can be coated with bio-based polymers in order to obtain better water barrier properties, for instance PLA or bio-based Polyethylene. Coating paper with PLA is highly interesting since it can be composted.

Some advantages with paper are that it is light and strong, made from renewable resources, biodegradable and recyclable. Negative aspects are its water barrier properties and lack of flexibility (in comparison to plastics), but new paper materials are being developed that in the future potentially could compete with many plastics.

2.2.2 Bio-based composites and nonwoven materials

Plant fibres can also be mixed with bio-based polymers, forming a bio-based composite. Bio-based composites made from biodegradable polymers have a great
potential, since they can be composted. Two types of composites were investigated; bio-based composites from paper pulp mixed with PLA-fibres and PLA-nonwovens.

Bio-based composites made from paper pulp and PLA-fibres are not commercially available, but are being researched and developed at Innventia AB. These composites obtain different properties depending on the pulp and PLA-ratio. The presence of PLA makes the material biodegradable but also allows it to be heat-sealed and heat-labelled. The blends used in this project have a textile-like expression and were prepared by Hanna Skoglund and Anna Nilsson. For further reading, see their degree project *Material Identity Crisis* (2015).

Various nonwoven materials were examined. Nonwoven materials are fabric-like materials with similar elements as textiles. The main difference is how they are joined. Nonwovens are like the name indicates not woven, knitted or similar, but instead bonded in different ways (ISO 9092:2011) more like a composite. Bio-based nonwovens can be made from for example PLA fibres.
3. Methodology

This chapter will briefly describe the methods used in the project. Initially the procedure will be presented followed by the methods used in the different phases.

3.1 Procedure

The product development process was based on Ullman (2010). Broadly speaking, the strategy was to investigate the problem thoroughly, study the latest about bio-based materials, generate several concepts, evaluate them and narrowing down to a few concepts and further developing them to complete product concepts. See Figure 3.1 for the development process.

![Figure 3.1 The product development process.](image)

3.2 Problem definition

The importance of understanding the problem properly is essential in a product development project. To understand the problem, Tiger of Sweden's requirements and the end-user requirements were examined through semi-structured interviews and observations. A market research was carried out in order to investigate existing solutions. A study visit to the Tiger of Sweden warehouse in Copenhagen showed the current covers in the context of their use. The requirements were transformed into engineering specifications, which are measurable product requirements. The methods are briefly presented below.

3.2.1 Semi-structured interviews

A Semi-structured interview is a technique where the interviewer has a loose interview guide and can when it is appropriate deviate from the topic and follow up a different track (Cohen and Crabtree, 2006). This gives the opportunity to identify new tracks which broadens the perspective. Cohen and Crabtree (2006) also mention that it is preferable to voice record semi-structured interviews, since open-ended questions might lead to discussions and side-tracks which could be hard to transcript while interviewing. Semi-structured interviews provide qualitative data.
3.2.2 Qualitative observations

An observation is qualitative if it is based on the observer’s own perception, rather than quantitative measurements. The observation study was conducted to identify how the employees used the existing transport cover in the Tiger of Sweden stores. The observation was a simulation of a clothes delivery in a Tiger of Sweden store. The test subject was thinking out loud during the procedure and the scenario was voice-recorded. The observation provided idealized information of the management of the clothes covers.

3.2.3 Questionnaire survey

Surveys are generally used to capture information and opinions about a specific topic. Surveys can be conducted through internet, post, telephone or face-to-face (Ullman, 2010). Burgess (2001) describes the general process of a survey as: state the purpose of the study, identify target group, design the questionnaire, run a pilot study, conduct the main study and analyse the results. Generally, the questions in a survey should be in logical order grouped by topic and go from general to more specific. It is preferable starting out with behavioural questions before attitudes and opinions (Brace, 2008). In this project, a web-based self-completion survey was used. A self-completion survey was used because they are cheap and easily reach out to a large sample group.

3.2.4 Quality Function Deployment

The engineering specification was conducted with a Quality Function Deployment (QFD) matrix according to Ullman (2010). QFD is an effective method used for generating engineering specifications. The method turns customers’ requirements into measurable engineering parameters. Traditionally the method involves eight steps, but in this project the method was slightly modified into six steps. Each step is described below and the matrix position of the step is presented in Figure 3.2.
Figure 3.2 The position of the different steps in the QFD matrix. Step 1 is not included in the matrix since it is a preparatory step.

Step 1 - Identification of customers

The different customers that are using the product should be identified. It can be helpful going through the product’s life cycle in order to identify all the users in contact with the product. (The result from this step is not shown in the QFD matrix)

Step 2 - The customer requirements

This step defines the customer requirements. The requirements can be defined with help of interviews, surveys and observations.

Step 3 - Importance of the requirements

The importance of the customers’ requirements is weighted. There are different weighting methods, either an absolute scale of 1 to 10 can be used or allocating 100 points between the requirements. A 10-point scale was used in this project.

Step 4 - Generation of engineering specification

This step generates engineering requirements based on the customer requirements. Engineering specifications should be measurable, for an easy verification against a future product. The direction of improvement is also determined for each engineering requirement. The specifications could be maximized, minimized or set to an exact target.
Step 5 - Relation between customer’s requirements and engineering specifications

In this step each customer requirement should be related to the engineering specifications, either one or many. The relationship could be strong = 9 = ⬤, moderate = 3 = ☐, weak = 1 = ▲ or no relationship at all.

Step 6 - Targets of the engineering specifications

This step determines the importance of each engineering specification and sets specific target values for each engineering specification. The importance of the specifications is calculated by multiplying the weightings from step 3 with the relationships set in step 5. The relative weight of each engineering specification could then be calculated by dividing the sum with the total sum of all specifications. This relative weigh determines the importance of each specification.

3.3 Concept generation

The conceptual design phase was focused on generating ideas and solutions for the future product. Before that was possible, it was necessary to understand the functions of the product since *form follows function* (Ullman, 2010). In order to do that, a function analysis was made where a few main functions were identified and further broken down into sub-functions. The initial idea generation started out with several rough sketches and paper models. Structured concept generation was carried out with a morphological matrix and an idea generation workshop.

3.3.1 Morphological method

A morphological matrix is a structured method used for generating concept ideas for a defined problem. Firstly, the functions need to be defined for the future product. Secondly, several solutions should be designed for each function. Lastly, the solutions for each function can be combined into complete concepts (see Table 3.1). The strength of this method is that many concepts can be generated in a short amount of time.
Table 3.1 The morphological method showing three functions and three solutions for each function. A combination of the solutions could lead to a concept.

<table>
<thead>
<tr>
<th>Functions</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function 1</td>
<td>Solution 1.1</td>
</tr>
<tr>
<td></td>
<td>Solution 1.2</td>
</tr>
<tr>
<td></td>
<td>Solution 1.3</td>
</tr>
<tr>
<td>Function 2</td>
<td>Solution 2.1</td>
</tr>
<tr>
<td></td>
<td>Solution 2.2</td>
</tr>
<tr>
<td></td>
<td>Solution 2.3</td>
</tr>
<tr>
<td>Function 3</td>
<td>Solution 3.1</td>
</tr>
<tr>
<td></td>
<td>Solution 3.2</td>
</tr>
<tr>
<td></td>
<td>Solution 3.3</td>
</tr>
</tbody>
</table>

3.3.2 Idea generation workshop

An idea generation workshop could be designed in various ways depending on the purpose and the project phase. This workshop was designed for a well-defined problem and the main purpose was to get more concept ideas and new tracks to follow. The workshop was scheduled to take two hours, divided into three sections: introduction, idea generation and material selection.

The introduction consisted of a presentation of the participants, a project description, a status report as well as purpose and goals of the workshop.

The idea generation was based on a morphological matrix with predefined functions. The participants had five minutes each to generate solutions that took the functions into account. The notes from each section were placed on a wall and the different solutions for each function were further combined into concepts in pairs.

Each pair was also meant to discuss potential material candidates for their generated concepts. A material sample bank was present at the workshop, used for inspiration while selecting materials for the generated concepts.

3.4 Concept selection

In order to select the most potential solutions a decision matrix, Pugh’s method, was used in combination with discussions with the project’s contact person at Tiger of Sweden.

Ullman (2010) describes Pugh’s method as an evaluation matrix used for comparing concepts against each other. The method scores the concepts relative to a datum on defined criteria. The criteria are based on engineering specifications and required functionalities. Each criterion could be weighted, either with a 5-point scale or a relative
weighting totalling 100%. The concepts are then scored better, equal or worse than the datum. Different scoring methods can be used. For this project +2 = much better, +1 = better, 0 = same, -1 = worse and -2 = much worse. The method is not necessary used to select a winner, but rather to identify strengths and weaknesses of the generated concepts. In order to decrease the subjectivity, various members of the design team should make the evaluation for comparison of the results (Ullman, 2010).

3.5 Product generation

The product refinement was supported with a perception study and prototypes. The methods are described in the following sections.

3.5.1 Perception study

The material selection was based on two methods, Pugh’s matrix, described in the previous section and a perception study. The perception study was performed with two test groups, one expert group consisting of employees from Tiger of Sweden (16 people) and one potential consumer group (12 people), mainly consisting of students. The perception study consisted of 13 material samples which were evaluated one at the time with respect to five attributes. The five attributes were evaluated against a seven-point scale, where 1 = Does not correspond at all and 7 = Corresponds a lot. The evaluation was based on the participants' sensorial experience. The purpose of the test was to get a subjective feedback of how well various material candidates were suited for the application. The test was designed in collaboration with Dr. Siv Lindberg and MSc. Karin Edström at Innventia AB.

The results were analysed and compared in Microsoft Excel per attribute with a one sample t-test, which was proposed and explained by Dr. Siv Lindberg. A one-sample t-test is a statistical method used for hypothesis testing. For this application, the t-test was used to test if the mean value for a particular sample was significantly different from the mean value for all samples, the global mean value. A result is significant if the probability obtaining the result by pure chance is less than a predetermined significance level, \( \alpha \), in this case 5%. The t-value is calculated as

\[
t - value = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}
\]

(Stone & Ellis, 2006)

where \(\bar{x}\) = sample mean value, \(\mu_0\) = null hypothesis - global mean value, \(s\) = standard deviation of each sample and \(n\) = number of test persons. \(s\) was calculated with Excels built-in function “STDEV.S”.

The t-values are compared with the so called critical t-value, which was determined by Excels built-in function “T.INV.2T”. This is the two-tailed t-value which means that the function splits the significance level (\(\alpha\)) in half and tests from two directions if it is
significantly different from the null hypothesis in the top and bottom 2.5% of a probability distribution curve (UCLA, 2015?). If the absolute t-values are greater than the critical t-value, they can be assumed to be statistically significant (and null hypothesis is rejected). Only statistically significant results were analyzed in the test.

3.5.2 Prototypes

A prototype is a physical model of a product being developed. A proof-of-concept model is a prototype representing the function of the product. It can be used for evaluation against the engineering specification and test the overall performance of a concept. (Ullman, 2010)

The appearance of a product concept can be illustrated by visual images or CAD-models. In this project visual images were used since a CAD-software would involve unnecessary complexity.
4. Problem definition

This chapter presents the procedure of defining the problem along with the results. The first four sections in this chapter did not run in subsequent order, but ran parallel. The chapter results in the essence of the problem definition - the engineering specifications.

4.1 Market analysis

The purpose of the market analysis was to investigate existing solutions of garment bags and transport covers. However, transport covers similar to the one Tiger of Sweden are currently using are standard in the industry and only small variations were identified. Hence, the market analysis was focused on garment bags and their different functions, attributes and materials.

The market analysis was conducted through the Google search engine, with keywords such as “garment bag” with 4.580.000 hits, “suit cover” 426.000 hits, “clothes cover” 150.000 hits and “clothing cover” 118.000 hits.

**Functions** identified were: carrying handles, garment identification, nametag, zipper, hanger eyelets, hanger hook flap, locker, turbo valve and push buttons.

**Attributes** discovered were: space-saving, water-proof, odourless, insect protection, dust protection, low weight, durable, breathability, acid free, easily cleaned and flexible.

**Frequently represented materials** were: Low density Polyethylene (LDPE), Nylon, Polypropylene (PP), Polyester, Polyethylene Vinyl Acetate (PEVA), Poly Vinyl Chloride (PVC), Canvas, Cotton twill and nonwoven-materials.

4.2 Tiger of Sweden’s value chain

Mapping out Tiger of Sweden’s value chain involved several interviews, a store visit, a field trip to Copenhagen and a documentation video from the logistic centre in Romania. Interviews with Product Director Tina Broman provided an overall picture of the transport process from production in Romania to the retail stores in Scandinavia. However, to find out detailed process steps, further investigation was necessary.

4.2.1 Store visit at Tiger of Sweden

A store inventory was visited at Torsgatan 4 in Stockholm. The visit included an observation study and a semi-structured interview with the store manager Linda Lindqvist. The store manager was supposed to simulate the scenario of a clothing delivery, from the truck until the clothes were hung in the store. Lindqvist was thinking out loud and the process was voice recorded. After the observation, an open ended
interview was conducted in order to discuss the observed procedure. The delivery procedure can be described as following:

- The garments hang in the truck on metal tubes perpendicular to the driving direction or hang inside a standing cardboard box.
- The garments are moved from the truck to the store on clothing racks.
- Normally the garments arrive at the store’s storage room, but occasionally the unpacking takes place in the customer area in the store.
- The packaging slip is found and the transport covers are ripped of the garments.
- The hangtag attached on the garments is verified against the packaging slip and gets price labelled for price.
- The garments are carried out to the store and the plastic hanger is exchanged for a wooden/metal hanger.
- In the storage room the garments are organized after model, colour, quality and size.

Furthermore, Lindqvist mentioned that the clothes covers are seldom dirty or damaged. She also mentioned that in small stores, clothes covers are exposed to customers when the clothes are delivered. This is a problem, since the current clothes covers look cheap and unappealing, according to the Product Director Tina Broman.

4.2.2 Field trip in Copenhagen

The field trip in Copenhagen included a visit at the flat pack warehouse for IC group and two Tiger of Sweden stores in Copenhagen. The flat pack warehouse did not cover the handling of the clothes cover for hanging garments since most of the garments are folded in cardboard boxes. The main warehouse for hanging clothes is in Herning, Denmark. The visit at Copenhagen provided valuable information; the most important is presented below:

- Transport covers from other brands were shown, which were slightly different in terms of material and fit, although they were of the same overall design and cheap look.
- The delivery procedure at the warehouse in Herning was described: the garments are moved from the truck to the warehouse using tubes attached to the ceiling in the warehouse and are pushed forward to its location by the warehouse workers.
- If less than nine suits are delivered from the warehouse in Herning, they are hung secured inside a standing cardboard box. See Figure 4.1.
4.2.3 Documentation video from the logistic centre in Romania

The documentation video from the logistic centre in Romania presented following information:

- The hang tags are attached to the first buttonhole on the suits shortly after production.
- The garments are transported to the warehouse connected to the production site.
- The suits are placed on a skewer under the hanger and the polybags are put on and the polybags hang folded on a rack during this process. See Figure 4.2.
- The information stickers are attached to the polybags and the barcode is matched against the hang tag and attached in the upper right corner of the polybag, followed by the destination sticker.
4.2.4 The complete transport chain

The complete transport chain of the garments can be described as:

- Production of the suits at the logistic centre in Romania.
- Hangtags are attached to the first buttonhole on the suits.
- The garments are delivered to a warehouse in connection to the production.
- A plastic cover is put on the garment, followed by barcode and delivery stickers.
- The garments are loaded in the truck a certain order.
- The garments are hung on bars and the hangers are secured with a locking mechanism.
- The truck drives to various producers in the country until it is full.
- The truck goes to the warehouse in Herning where the garments are tracked.
- The garments are delivered to the stores in Scandinavia by truck in hanging cardboard boxes or hanging on bars.
- The clothes arrive at the store and the plastic cover is discarded.
4.3 Tiger of Sweden's requirements

This section presents Tiger of Sweden's requirements for the new clothes cover. The requirements are developed based on previous sections and several interviews with the Product Director of Tiger of Sweden, Tina Broman. The requirements of Tiger of Sweden are:

**Appearance**

- Communicate Tiger of Sweden's quality throughout the value chain

**Functionality for Tiger of Sweden**

**Efficient handling**

- Easy accessible hang tag
- Easy identification of the garment inside the cover
- Attachable barcode and delivery point sticker in the upper right corner.

**Protection**

- Be able to breathe
- Moisture protection
- Dust protection
- Protection in case of drop
- Odour protection

**Transport**

- Lightweight
- Thin

**Quality requirements for the plastic cover according to IC group**

- Must have small air holes for ventilation.
- Must be >10 cm longer than the garment in order to avoid wrinkles.
- Must be closed at the bottom to keep garment from slipping out of the cover if the garment slides off the hanger.
- Must not be more than 2.5 cm wider than the garment.

**Functionality for the end-user**

- Protect from dust and moisture
- Carrying possibilities
Environmental sustainability

- Completely or partially from a renewable material.
- Sustainable throughout the clothes covers life cycle.

4.4 End-user requirements

For identification of the end-user requirements a web-based survey was conducted with the questionnaire tool SurveyMonkey. The survey included 65 participants and was sent out on the social platform Facebook and internally to the employees at Innventia AB. The ages were spread over 18-65+, with an even distribution across the ages 25-64. The survey was conducted to find out why common people using garment bags, how they use them and what kind of garment bags they have got. The questions were ordered from general to more specific. In the beginning, there were closed multiple choice questions which later was followed by open questions.

The survey confirmed the predictions of how people used garment bags. The main findings were that most of the men received a garment bag when they bought a suit, while most of the women bought their own. The most popular usage was to travel, protect and store their clothes. Men use it for suits and tail-coats, while women use it mainly for dresses and coats. The most frequent words used in the description of their own garment bags were: zipper, plastic, black, fabric and nylon. Functionality that was missing was pockets, light weight and foldability. The most important functions and properties were (dust) protection, light weight and carrying possibilities. For a complete compilation of the survey see Appendix 1.

The conclusion from the survey was that protection and carrying possibilities was the most important features and that a low weight was desired.

4.5 Quality Function Deployment

The steps described in the previous sections provided necessary information to perform the QFD matrix, resulting in the engineering specifications. The QFD was conducted with a template from QFD Online (QFD Online, 2008). The QFD gives a deep understanding of the project and helps to generate engineering specifications, but the results were used as guidance, not as definitive truths. The resulting QFD matrix is presented in Appendix 2. The actual procedure and sub-results are presented below.

Step 1 - Identification of customers

There are several people that would use the new plastic cover: the employees at the logistic centre in Romania, the truck driver transporting the garments, the warehouse workers, the store employees and the end-user. This results in many different requirements that need to be satisfied in order to make a successful product.
Step 2 - The customer requirements

The customer requirements was based on the documentation video from the logistic centre in Romania (Chapter 4.2), the field trip in Copenhagen at IC Groups flat pack warehouse (Chapter 4.2), observation and interview with the store manager Linda Lindqvist at a Tiger of Sweden store inventory (Chapter 4.2) and several discussions with the Product Director Tina Broman.

Step 3 - Importance of the requirements

Each requirement were weighted with a ten-point scale and the QFD excel template was used to calculate the relative weighting, totalling 100%. Allocating the weightings was a difficult process since there were several customers to please in the different stages of the value chain. In order to simplify the process, all requirements were put on post-it notes and ranked in a list. Some requirements turned out to be equally important and were grouped together. The weighting was to a large extent based on discussions with the Product Director Tina Broman.

Step 4 - Generation of engineering specification

Some customer requirements were directly convertible to engineering requirements, while others needed several engineering requirements to describe them. Ideally, engineering requirements should be measurable in terms of a target with a unit. This rule requires that a certain target value is known and that the value can be verified against a future product. For some criteria, this was not the case, for example “Ventilation”, “Water protection” and “Low odour inlet”. However, there was a common understanding of the meaning of these. “Ventilation” meant that the clothes should be able to breathe, in other words, that the cover should not be completely air tight. “Water protection” means that the cover should not absorb water in case of short exposure to water splashes. “Low odour inlet” was an unnecessary criterion, since the garments are not exposed to odours. The reason it was kept was because there was not enough information to exclude it at that stage.

Step 5 & 6 - Evaluation and targets for the engineering specifications

The QFD showed that the four most important specifications were: “High score on a 5-point attractiveness scale ranked by Tiger of Sweden”, “Maximum production cost of 10 SEK”, “As low weight possible but < 150 gram” and "As thin as possible but < 1 mm".
4.6 Engineering specification

The QFD-study lead to in-depth understanding of the problem and resulted in several engineering requirements necessary for the development of the product concept. The complete engineering specification list was divided in “must have” and “should have” requirements, where the first were absolutely necessary and the others to be considered as wishes. “Must have” and “should have” requirements were divided in agreement with Tina Broman. The engineering specifications can be seen in Table 4.1 and 4.2.

Table 4.1 Engineering specifications - Must have requirements

<table>
<thead>
<tr>
<th>Must have requirements</th>
<th>Units</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Must be more attractive than the poly bag</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Access the hangtag in &lt; 5 s</td>
<td>[s]</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Possible identification of collar and stroke from the outside</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Attachable surface at the upper right corner</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Maximum weight of 150 gram</td>
<td>[gram]</td>
<td>&lt;150</td>
</tr>
<tr>
<td>Maximum thickness of 1 mm</td>
<td>[mm]</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Water protection</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dust &amp; dirt protection</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Yield strength enough carrying 5 kg</td>
<td>[kg]</td>
<td>5</td>
</tr>
<tr>
<td>The material must not create garment discoloration</td>
<td>True/False</td>
<td>True</td>
</tr>
<tr>
<td>The cover cannot cause chafing on other garment or covers</td>
<td>True/False</td>
<td>True</td>
</tr>
<tr>
<td>Maximum production cost (purchase price) of 10 SEK</td>
<td>[SEK]</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Material &gt; 20 % from renewable sources</td>
<td>[%]</td>
<td>100%</td>
</tr>
<tr>
<td>Recyclable</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 4.2 Engineering specifications - Should have requirements

<table>
<thead>
<tr>
<th>Should have requirements</th>
<th>Units</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>High score on a 5-point attractiveness scale ranked by Tiger of Sweden</td>
<td>Points</td>
<td>5</td>
</tr>
<tr>
<td>The cover should be &gt;10 cm longer than the garment</td>
<td>[cm]</td>
<td>&gt;10</td>
</tr>
<tr>
<td>The cover should not be more than 2.5 cm wider than the garment</td>
<td>[cm]</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Low odour inlet</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Protection of dirt inlet in case of drop</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>The cover should preferably be closable at the bottom</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Carrying possibilities</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Lower embodied energy in primary production than LDPE</td>
<td>[MJ/kg]</td>
<td>&lt;76</td>
</tr>
<tr>
<td>Lower CO2 footprint in primary production than LDPE</td>
<td>[kg/kg]</td>
<td>&lt;2.8</td>
</tr>
<tr>
<td>Industrial manufacture possibilities within 3 years</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
5. Concept generation

This chapter describes the concept generation process, which consisted of three main steps: understanding the functions, generation of ideas and investigation of material candidates.

5.1 Function understanding

Before generating ideas, it is essential to know the functions the product should have. The functions represent the purpose of the product and without knowing the purpose the wrong problem might be solved. As Ullman (2010) states, the function tells what the product must do, while the form describes how it should be done.

The functions were identified by listing all individual sub-functions and grouping them into five main function categories. The functions are illustrated in Figure 5.1.

<table>
<thead>
<tr>
<th>Storage</th>
<th>Information</th>
<th>Protection</th>
<th>Transport</th>
<th>Promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Hang in garment</td>
<td>- Wear barcode</td>
<td>- Protect the garment from:</td>
<td>- Carrying the garment</td>
<td>- Promote the garments</td>
</tr>
<tr>
<td>- Take out garment</td>
<td>- Wear delivery point sticker</td>
<td>- Dust</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Open/close the cover</td>
<td>- Identify the garment</td>
<td>- Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Store garment</td>
<td>- Access the hangtag</td>
<td>- Odor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ventilate the garment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5.1* The functions of the clothes cover grouped in five main categories.
5.2 Idea generation

The idea generation process consisted of multiple sketches, scale models and an idea generation workshop. Generating several ideas is of great importance, since only a small percentage of the ideas are usually useful. Hence, the more ideas generated the greater chance to success. Research shows that only 2% - 3% of generated ideas have great potential and 10% - 25% are worthy to continue working on (Michanek & Breiler, 2007).

5.2.1 Sketches and scale models

The idea generation began with loads of rough sketches and small paper mock-ups. The idea generation was an iterative process, where concepts were created and evaluated repeatedly until a comprehensible amount of ideas were left. Figure 5.2 illustrates a selection of rough sketches from the idea generation.

![Figure 5.2. Sketches from the initial idea generation.](image)

5.2.2 Idea generation workshop

A structured workshop was performed with six people from different professional backgrounds. The participants were:

- Sebastian de Arteaga (Author, MSc student, KTH)
- Tina Broman (Product Director, Tiger of Sweden)
- Dr. Mikael Lindström (Senior Research Manager, Innventia)
- Dr. Siv Lindberg (Cognitive Psychology, Innventia)
- MSc. Karin Edström (Project Manager, Innventia)
- Dr. Marie-Claude Béland (Research and Business Development, Innventia)
The purpose of the workshop was to get new approaches and tracks to work further on. The workshop was two hours long, divided into three sections: introduction, idea generation and material selection.

The introduction began with an introduction of the participants, a background description of the project and the purpose and goals with the workshop.

The idea generation phase consisted of a collective morphological matrix (method described in chapter 3.3.1). The following predefined functions were used:

- How do you put in/take out the garment?
- How is the hanger attached?
- How is the garment identified from the outside?
- How is the clothes cover carried?
- How and where could the logo be placed?

The functions were presented one at the time and the participants had five minutes on each function for generating solutions. However, animated discussions and the need to clarify certain ideas reduced it to a couple of minutes per function. A good advice is to have a warm-up exercise in order to make the participants comfortable. The exercise resulted in a large number of ideas; see Figure 5.3, where the darker post-it notes were the functions and the lighter the generated solutions.

Figure 5.3 Generated sub-functions at the workshop.
The next exercise was conducted in pairs which were meant to combine the generated solutions into concepts and find suitable material candidates. The workshop resulted in a total of 90 solutions. All solutions were grouped after similarity and are presented in Appendix 3. A selection of some potential ideas from the workshop is presented in Figure 5.4.

![Figure 5.4](image)

**Figure 5.4** Some potential ideas from the workshop: (1) A rolled up clothes cover, (2) Hanger insert sideways, (3) A clothes cover like a “rain poncho”, (4) RFID or NFC for tracking of garments and (5) A cover foldable like an accordion.

### 5.2.3 Concept ideas

The initial idea generation and the workshop resulted in five more defined concepts ideas. The concepts presented were not necessarily technically solved, but judged as feasible.

**Concept 1**

This concept has a plastic zipper lock underneath or on the side for hanging in or taking out the garment. The cover can be folded allowing it to be carried like bag. The hanger is hidden and attached to the backside when carrying it. This allows the end-user to carry it freely without having to hold onto the hanger. The concept proposal is presented in Figure 5.5.
Concept 2

This concept also has a plastic zipper lock underneath or on the side for hanging in or taking out the garment. The concept has no handles and the cover needs to be carried with the hanger hook. The concept is mainly aimed as an exclusive transport cover, rather than a customer focused product. Figure 5.6 illustrates the concept.

Figure 5.6 Visual illustrations of Concept 2 in two different designs.
Concept 3

In this concept the two panels of the cover overlap slightly either vertically or horizontally in the middle and this is where the garment is inserted. The concept can also be folded allowing it to be carried like a bag. See Figure 5.7.

Figure 5.7 Concept 3, where the material overlaps vertically to the left and horizontally to the right. The images showing them in two modes: hanging and folded.

Concept 4

In this concept the hanger is enclosed like a “rain poncho”. The concept has no handles and the cover needs to be carried in the hanger hook. The sealing/locking method was not determined, but a button, hook or Velcro was considered. Frames could be used for a more exclusive feeling if it’s completely transparent. This concept can be classified more as a transport cover, than a customer-focused solution. See Figure 5.8 for a visual image.

Figure 5.8 Visual illustrations of Concept 4 in two different designs.
Concept 5

This concept opens sideways with the protruding piece of material illustrated in the Figure 5.9, which can be attached either to the frontside or the backside. When it is attached to the backside the cover is half open, which makes the garment accessible.

![Concept 5 Image]

Figure 5.9 A visual image showing Concept 5 open, closed and folded.

5.3 Material candidates

The aim of the initial material research was to gather several interesting materials, both in terms of appearance and properties.

The research included examination of grocery packages, plastic bags, garment bags and various bio-based plastics and composites. Potential materials were collected and cut out to quadric samples. The aim was to collect bio-based materials or materials which could work as benchmarking or pure inspiration. A selection of collected materials is presented in Figure 5.10.
Figure 5.10. The material sample collection for inspiration and benchmarking.

The material collection consisted of PE films with different densities, thicknesses and surfaces, sheets of PP, bio-degradable Mater-bi bags, PLA-films, paper and paperboard, nonwovens and composites.
6. Concept selection

This chapter presents the concept selection process. The concepts were systematically evaluated with the decision-matrix Pugh’s method and finally selected based on the results and feasibility evaluations.

6.1 Pugh’s method

Pugh’s method was used to evaluate the generated concepts in a structured manner and make a selection of a few concepts to continue with for further development.

The five concepts generated in the previous chapter were evaluated. Initially all concepts were evaluated in the same decision-matrix, which was problematic since the concepts were not focused for the same application; hence they couldn’t have the same criteria for evaluation. This resulted in two matrices and the concepts were divided into two groups: solutions mainly used for transport (Concept 2 and 4) and solutions used for transport and the end-user (Concept 1, 3 and 5).

The criteria for comparison were divided into two groups: design and function requirements. The most basic requirements were not used for evaluation since all concepts fulfilled them, nor were the most specific engineering specifications were used, since the concepts were not refined enough to evaluate against them.

A five-point weighting scale was used to rank the importance between the criteria. The weighting was also conducted by Tiger of Sweden’s Product Director Tina Broman and the results were discussed in group with Dr. Marie-Claude Béland and MSc. Karin Edström, until agreement.

The evaluation was scored relative a datum. First, the existing plastic cover was used as a datum for both matrices. Later, it was concluded that it was not a fair judgement, since some of the concepts are intended to be used for transport and as a garment bag for the end-user while the existing cover is only used for transport. Hence, the matrix with concepts used for transport and the end-user, the most potential concept, Concept 1, was used as a datum. However, the concepts mainly intended for transport, like the existing cover, still used the existing plastic cover as a datum. The resulted matrix for covers made mainly for transport is presented in Table 6.1.
Table 6.1. Pugh’s method evaluating concepts mainly focused on transport.

<table>
<thead>
<tr>
<th>Criteria for comparison</th>
<th>Weight</th>
<th>Poly bag</th>
<th>Concept 2</th>
<th>Concept 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td></td>
<td>Datum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appearance</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Simplicity</td>
<td>4</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td></td>
<td>Datum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of garment</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Easy access to the hangtag</td>
<td>4</td>
<td>-1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hang in/take out garment</td>
<td>4</td>
<td>-1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Protection of dirt inlet in case of drop</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted total</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The resulted matrix for covers intended for transport and the end-user is presented in Table 6.2.

Table 6.2. Pugh’s method evaluating concepts focused on transport and the end-user.

<table>
<thead>
<tr>
<th>Criteria for comparison</th>
<th>Weight</th>
<th>Concept 1</th>
<th>Concept 3</th>
<th>Concept 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td></td>
<td>Datum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appearance</td>
<td>5</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Simplicity</td>
<td>4</td>
<td>0</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td></td>
<td>Datum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of garment</td>
<td>4</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Easy access to the hangtag</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hang in/take out garment</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Protection of dirt inlet in case of drop</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Carrying possibilities</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted total</td>
<td>-1</td>
<td>-5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.2 Selection

Pugh’s method provided valuable information about the strengths and weaknesses with the concepts. In this section the results will be discussed from Pugh’s method and the final selections will be presented.

According to Table 6.1, the weighted total is higher for Concept 4 than Concept 2. This is because Concept 2 performs worse at the criteria “Easy access to the hang tag” and “Hang in/take out the garment”. However, the team was in agreement that Concept 2 had a better appearance and felt technically more feasible, which outweighed the criteria which it performed worse at. Hence, Concept 2 was chosen for further development and Concept 4 was excluded.

In Table 6.2, both Concept 3 and 5 had a negative weighted sum compared to their datum, Concept 1. Concept 1 performed better in “Appearance” and “Identification of garment” than both of the others. Further, it scored higher at “Simplicity” than Concept 5. On the other hand, it was worse in “Easy access to the hangtag” and “Hang in/take out garment”. Concept 1 was chosen for further development.

In both matrices, the chosen concepts performed worse in “Easy access to the hang tag” and “Hang in/take out the garment” which were judged as acceptable trade-offs for a better appearance.
7. Product generation

This chapter will present the development from idea concepts into more defined product concepts. The chapter includes the form determination, including the overall design of chosen concepts. Further, it presents the material selection, which involves a perception study, a technical evaluation and the final material selection. Finally, it presents the prototypes of the concepts.

7.1 Form determination

The form determination was an iterative process conducted with sketches and technical drafts.

7.1.1 Form determination for Concept 1

In Concept 1, the most challenging function to solve was how to avoid interruption from the hanger when carrying the cover once folded. The resulting solution for this was to attach the hanger to the backside in a reinforced attachment with two vertical holes. This holds the garment in position in the cover, while the force from the weight of the suit acts on the outer layer and transmits to the handles. The solution is presented in Figure 7.1.

![Attachment for the hanger hook](image)

**Figure 7.1** The hanger hook is inserted in the vertical holes on the backside of the cover which allows it to be carried without having to hold onto the hanger hook.
Different closure mechanisms where the garment is inserted were investigated. The solutions for sealing with the highest potential were zip or slide-locks, touch fasteners or press-fastener buttons (see Figure 7.2).

**Figure 7.2** (1) Zip-lock bag by Packoplock, (2) slider lock bag by Ziploc®, (3) touch fastener by Aplix® and (4) press fasteners buttons by Prym.

The selected solution was to use press fastener buttons. The motivation for this was because they are inexpensive standard components, which provided additional functionality when closing the cover. The press fasteners allowed the handles to be folded, when transporting and storing the cover and once the end-user wants to carry the cover, the folded sides can be connected with the same buttons. See Figure 7.3.

**Figure 7.3** Illustrating the press fasteners and their functions.

However, the same principle could be applied with the touch fasteners, where Aplix® Easy-lock and Velcro® Press-Lok are good candidates. An even cheaper solution would be no sealing at all. IC group claims in their packaging instructions that sealed
covers are required, but the majority of the existing covers are not sealed, which is contradictory. The complete draft can be seen in Appendix 4.

7.1.2 Form determination for Concept 2

For Concept 2 various closure mechanisms were investigated, where the most promising solution was a plastic zip or slide lock. The motivation was because they are simple, inexpensive and available from many manufacturers. On the other hand, an advantage with touch fasteners are that they do not need perfect alignment when sealed. The zip lock needs to be over-dimensioned for easy sealing.

Concept 2 was initially designed to be used as a transport cover and not for customer use. However, an eyelet can easily be attached below the zip lock lips at the bottom of the cover, which would allow it to be folded and carried in the hanger by inserting the hook in the eyelet. Many existing garment bags have that solution. This would be an inexpensive add-on to make Concept 2 usable for the end-user.

Concept 2 and its functionality are presented in Figure 7.4. The complete draft can be seen in Appendix 5.

![Figure 7.4 Concept 2 and its functionality.](image)

7.2 Material selection

The material selection involved a perception study and a technical evaluation.
7.2.1 Perception study

A perception study was conducted with 28 participants evaluated 13 material samples based on their sensorial experience. There were two different test groups: one from Tiger of Sweden and another consisting of potential consumers. The Tiger of Sweden group consisted of purchasers, designers, production coordinators and store managers in the ages of 24-41, with a majority in the ages of 25-35. The consumer group included mostly students in the ages of 23-28.

The test consisted of 13 material samples, an information sheet and a fill-in form for each sample. The information sheet contained basic information (age, sex and profession), project background information and test instructions (see Appendix 6 for the actual paper). The fill-in form was used for the evaluation; containing five different attributes which Tiger of Sweden wanted to be associated with and a seven point scale below each attribute (see Appendix 7 for the fill-in form). The attributes were: Luxurious, Masculine, Premium, Unique and Modern. Each material was marked with a number, which were meant to be written on each evaluation sheet. During the test, a test leader was present for questions. The test ended with a brief discussion with the participants for feedback about the materials and the concepts. The test leader was Sebastian de Arteaga (author), assisted by the Project Manager at Innventia AB, MSc. Karin Edström, who led four of the tests. Each test took about 20-30 minutes.

The materials used were plastic, paper and fabric-like composites, see Figure 7.5. There were five plastic materials: (1) white glossy 140 µm PE film, (2) white matte 170 µm PE film, (10) transparent 40 µm PLA film, (11) hazy transparent 60 µm PE film and (13) semi-clear 70 µm PE film. The paper-based materials were: (4) white delicate 70 µm paper, (8) white smooth 420 µm paperboard, (9) black rough 225 g/m² paper and (12) white smooth 120 µm craft paper. The composites were: (3) dark grey crimped 600 µm pulp-PLA composite, (5) black shiny 300 µm coated polyester fabric, (6) black matte 440 µm nonwoven and (7) grey rough 540 µm pulp-PLA composite. The majority of the samples were meant to represent potential material candidates for the transport cover. However, some materials were substitutes for the real material when these were not available. Five of the samples (4, 5, 6, 8 and 11) were used by Tiger of Sweden in existing packaging products. A detailed material list is presented in Appendix 8.
Figure 7.5 Material samples grouped by material type. Sample 10, 11 & 13 are transparent.

A one sample t-test (described in chapter 3.5.2) was conducted in order to determine if the results were significantly different from the null hypothesis. The null hypothesis was that all samples have the same value in respect to the attributes.

**Tiger of Sweden’s test group**

The significant results from the Tiger of Sweden’s participant group are presented in Table 7.2. The presented results are for the samples that scored over and under the global mean value and had the highest and lowest average scores. The global mean value is the mean value of all samples for a particular attribute. A compilation of all the results is presented in Appendix 9.
Table 7.2 The significant sample results from Tiger of Sweden’s test group which were over and under global mean value and scored highest and lowest.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Global mean value</th>
<th>Over global mean value</th>
<th>Under global mean value</th>
<th>Highest mean value</th>
<th>Lowest mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxurious</td>
<td>3.4</td>
<td>2, 5, 9</td>
<td>10, 11, 13</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Masculine</td>
<td>3.7</td>
<td>5, 6, 9</td>
<td>4, 10, 11, 13</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Premium</td>
<td>3.4</td>
<td>5, 9</td>
<td>10, 11, 13</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Unique</td>
<td>3.0</td>
<td>2, 3, 5</td>
<td>11, 13</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Modern</td>
<td>3.4</td>
<td>2, 5</td>
<td>11, 13</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

It can be deduced from the results that sample 2, sample 5 and sample 9 score better than global average on three or more attributes, which indicates that these materials are in accordance with Tiger of Sweden’s values. While sample 10, sample 11 and sample 13 are not consistent with Tiger of Sweden’s values. Overall best is sample 5, which actually is Tiger of Sweden’s existing material for their luxurious garment bag. Worst performing against the attributes are sample 11, which is Tiger of Sweden’s existing transport cover.

Potential consumer test group

The significant results from the potential customer participant group are presented in Table 7.3.

Table 7.3 The significant sample results from the consumer test group which were over and under global mean value and scored highest and lowest.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Global mean value</th>
<th>Over global mean value</th>
<th>Under global mean value</th>
<th>Highest mean value</th>
<th>Lowest mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxurious</td>
<td>3.3</td>
<td>2, 3, 5, 7</td>
<td>4, 10, 11, 13</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Masculine</td>
<td>3.1</td>
<td>5, 6, 7, 9</td>
<td>4, 10, 11, 13</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Premium</td>
<td>3.4</td>
<td>2, 3, 5, 7</td>
<td>4, 10, 11, 13</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Unique</td>
<td>3.2</td>
<td>3, 7</td>
<td>11, 13</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Modern</td>
<td>3.8</td>
<td>5</td>
<td>11</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

These results indicate that sample 3, sample 5 and sample 7 are in accordance with Tiger of Sweden’s values, since they score better than the global average on three or more attributes. While sample 4, sample 10, sample 11 and sample 13 scores below
global average. Highest average score have sample 5 and sample 7, while sample 11 has the lowest average value.

**Comparison of results between the groups**

For the attribute Luxurious, the Tiger of Sweden’s participant group scored sample 5 the highest, while the consumer group scored sample 7 highest. Sample 5 scores significantly above average for both groups, but sample 7 has no significant result from Tiger of Sweden group. The reason for this could be that sample 7 got a fabric-like look and that the employees at Tiger of Sweden have a deep knowledge in fabrics and consequently are more critical.

The results for the attribute Masculine are consistent for both groups, where sample 5 has the highest score and 11 the lowest. All samples which scored above the global average had dark colors, which probably influenced the result.

For the attribute Premium, the Tiger of Sweden participant group scored sample 5 the highest, while the consumer group scored on sample 7 highest. Equally, sample 5 scored significant above average for both groups, while sample 7 had no significant results from the Tiger of Sweden group.

For the attribute Unique the results from both groups were consistent, where sample 3 scored highest and sample 11 lowest.

The results were also consistent for the attribute Modern, where sample 5 scored highest and sample 11 lowest.

None of the groups showed significant opposite results, meaning that no sample scored significant above average for one group but under average for the other.

**Conclusion**

The test indicated that the polyester composite, sample 5, performs well for several attributes. The pulp-PLA composite, sample 7, was ranked the most luxurious and premium by the consumer group. The most unique material according to the test results was the textured pulp-PLA sample 3.

The plastic film that scored overall highest was the two sided matte/glossy, 170 µm thick polyethylene film, sample 2. Three people claimed that two sided materials feel thought-out and professional. This might be a reason why sample 2 scored significantly higher on several attributes than the similar glossy PE-film of the same thickness.

Using the same reasoning a test person argued about the two sided paperboard, sample 8, but in the opposite direction; that a nice front and a boring back gives a bad
impression. Hence, two sides are not necessarily positive if there is no underlying motivation behind it.

Numerous test persons claimed that stiffer and thicker plastic materials are more luxurious and of higher quality. Several disliked when plastic wrinkles.

The test results showed that transparent plastic scored low in comparison with the other materials. Many test persons claimed that transparent plastic feels cheap, in particular hazy transparent plastics.

The paper material that scored overall highest was the black, 225 g/m² paper, sample 9. The other paper materials scored low, and what distinguished them was that they were thin and fragile.

The color might have affected the results on several attributes, in particular the attribute Masculine.

Finally, the attributes premium and luxurious showed very similar results, which is understandable because of the similarity of the words.

### 7.2.2 Technical evaluation

In addition to the material experience, a material has to fulfill various technical parameters in order to work well for its application. Important material properties are stated in Table 7.4.

<table>
<thead>
<tr>
<th><strong>Table 7.4</strong> Technical material requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile strength</strong></td>
</tr>
<tr>
<td><strong>Elongation at break</strong></td>
</tr>
<tr>
<td><strong>Water vapor transmission</strong></td>
</tr>
<tr>
<td><strong>Optical properties</strong></td>
</tr>
<tr>
<td><strong>Friction</strong></td>
</tr>
<tr>
<td><strong>Bio-based content</strong></td>
</tr>
</tbody>
</table>
The transparency requirement excluded paper materials and bio-based composites as mono materials, although they were still considered as components of the construction. The remaining material candidates for the main construction were PLA-based plastic, starch-based plastic and bio-based polyethylene. Cellulose-based plastic was excluded early in the process due to water sensitivity and brittleness. However, Innventia AB is working on new cellulose-based materials that could potentially be used for this type of application.

PLA-based plastic in comparison to the other candidates has the advantage of good tensile strength and optical properties. On the other hand, the disadvantages are the brittleness (low elongation at break), water vapor transmission in warmer climates and limited recyclability (Tolinski, 2011).

The advantage of starch-based plastics is that it is compostable, but this was not required for this application. An advantage with starch-based plastics is that they have good ventilation. Disadvantages are moisture sensitivity, brittleness in absence of plasticizers, low transparency and the comparatively low bio-based content.

Bio-based polyethylene or polyethylene obtained from renewable content, has the advantage of great flexibility, good water barrier, high renewable content, excellent manufacturability and recyclability. One disadvantage is the durability, if the waste is not disposed properly.

### 7.2.3 Selection

Technically, bio-based polyethylene possesses the most suitable properties for this application, mainly because of its flexibility, water barrier properties and great manufacturability. The flexibility of polyethylene allows it to be foldable, without creating permanent deformations, wrinkles, to the same extent as other candidates. According to the perception study, clear transparent material is preferred over hazy materials. Hence, a low density bio-based polyethylene with high transparency was selected.

The perception study also indicated that thicker materials raise the feeling of quality, which suggests that a slightly thicker film should be used. Bio-based PE is available in a wide range of thicknesses, since the same manufacturing equipment can be used as for traditional PE. On the other hand, from an environmental perspective a thicker material would mean unnecessary material usage.

Finally, a mono material construction is preferable over using a combination of several materials. A single material is easier to recycle and less complex to produce.
7.3 Prototypes

Three full-scale proof-of-concept demonstrators were made. Two prototypes were made for Concept 1, one functional model and another showing the appearance. For Concept 2 a functional model was made.

7.3.1 Prototype for Concept 1

The functional prototype for Concept 1 (see Figure 7.6) was made in a semi-transparent 150 µm LDPE film (not the correct material, but similar thickness). The prototype was made according to the technical draft shown in Appendix 4. The film sheets were heat sealed with baking paper and a soldering iron. Baking paper was put under and over the two plastic sheets, which were heat sealed together with the soldering iron and a metal ruler to get it straight. In order to not melt through the plastics, it was important to have a soft pressure and draw the soldering iron quickly back and forth with a constant speed. The last step was to attach the press fastener buttons.

![Figure 7.6 Photography of functional prototype for Concept 1.](image)

The demonstrator showing the appearance was similar to the model described above, despite that it was spray painted with acrylic paint. The logotype was made with an acrylic stencil cut out with an Epilog Fusion laser cutter. However, acrylic spray paint does not stick very well on polyethylene without surface treatment, which made the colored prototype unusable due to its fragility.
7.3.2 Prototype for Concept 2

The functional prototype for Concept 2 (see Figure 7.8) was made with the same technique and material as Concept 1, but according to the draft showed in Appendix 5. The plastic zip lock sealing was not demonstrated in the prototype.

Figure 7.8 Photography of functional prototype for Concept 2.
8. Final concepts

This chapter presents the final concept proposals including the design, features and material selection.

8.1 Concept 1

Concept 1 is a premium transport cover for suits to be used from production to the store and then from the store to the customer’s home. The cover gives an exclusive expression throughout the value chain and creates an added value for the end-user. See Figure 8.1 for a visual image of the concept.

![Figure 8.1 Rendered image of Concept 1 in the three different modes.](image)

The garment is inserted underneath and sealed by folding the handle and attaching it to the backside with press fasteners buttons. When transporting and storing the garment, the handles are folded both above and below with the press fasteners. Once the end-user wants to carry the cover, it can be folded and connected with the same buttons that attach the handles. When it is folded, the hanger is hidden and attached at the backside to a reinforced attachment. This holds the garment in the cover, while the force from the weight of the suit acts on the outer layer and transmits to the handles.

In short, the concept has three main functions: protecting the garment from production to retail, storing the garment and allowing the end-user to carrying it folded like a bag. Figure 8.3 illustrates the clothes cover stored in the warehouse to the left and the customer carrying it to the right.
Figure 8.3 The clothes cover hanging on a garment rack (left) and a customer carrying it (right).

The material chosen for this product concept is bio-based low density polyethylene. Polyethylene possesses the most suitable properties for this application due to its flexibility, water barrier properties and great manufacturability. The material has also proven its function since the existing transport cover is made in polyethylene, although not from renewable resources. Bio-based polyethylene is made from sugarcane, instead of fossil fuels, but still has the same performance as regular polyethylene and could be recycled in the existing recycling stream. The press fastener buttons can be produced in bio-based high density polyethylene, which makes the construction completely in polyethylene. The film thickness should be 150 µm, which gives the product fastness and a high quality look. A technical draft is presented in Appendix 4.

8.2 Concept 2

This product concept is a premium transport cover for suits to be used from production to retail. The cover gives an exclusive expression and communicates throughout the value chain the high-end brand that Tiger of Sweden is. The main purpose of the product is to protect the garment during transport, but the customer will also be able to use it to protect their suit when storing it at home. Figure 8.4 illustrates Concept 2.
The cover opens from the bottom, where it is sealed with a re-sealable plastic zip lock. The suit cover can be folded by inserting the hanger hook into the eyelet at the bottom of the suit cover. This allows it to be carried in the hanger hook.

Concept 2 is proposed to be produced in 150 µm thick bio-based low density polyethylene, like Concept 1. The eyelet for inserting the hanger hook can be produced in bio-based high density polyethylene.

8.3 Visionary concepts

A visionary compostable concept was also investigated. Combining PLA and paperboard or PLA and a pulp-PLA composite would make a compostable product. This concept is based on Concept 2, but has a stiffer paperboard or pulp-PLA backside and a clear PLA-film front side. This would allow Tiger of Sweden to use it during transport and instead of throwing it in the trash for incineration (as the existing cover); it could be industrially composted and turned into water and carbon dioxide. The logotype could be printed on the PLA-surface or embossed in the paperboard or pulp-PLA backside. Figure 8.5 shows different designs of the concept proposal. This concept is in a very early stage and needs further investigation. Innventia intends to show in autumn 2015 a reduced-scale demonstrator using entirely cellulose-based newly developed materials based on this concept.
Figure 8.5 The PLA and paperboard concept in different colors.
9. Conclusion

This chapter will present the main findings and conclusions in this project.

9.1 Web-based survey

According to the web-based survey people use garment bags for travelling, protection and clothes storage. The most important functions and properties are dust protection, carrying possibilities and low weight.

9.2 Perception study

- The perception study indicates that the black coated polyester fabric (sample 5) is perceived in accordance with Tiger of Sweden’s values: Luxurious, Masculine, Premium, Unique and Modern.
- According to many potential consumers, the textile-like pulp-PLA composite (sample 7) is perceived as luxurious and premium.
- Among the plastic samples, the two-sided matte 170 µm polyethylene film (sample 2) was most related to Tiger of Sweden’s values. An explanation could be because it was thicker than the other plastic samples and was two-sided.
- Numerous test persons claimed that they think thicker and stiffer plastics are more luxurious and of higher quality.
- It can clearly be deduced from the test that transparent plastics are not associated with Tiger of Sweden’s values, especially not hazy transparent plastic.
- Thin and fragile paper materials are not associated with Tiger of Sweden’s values for this application.

9.3 Material research

Starch-based plastics possess the property of biodegradability and are suitable for short time usage. Starch-based plastics are moisture sensitive, have low transparency and brittle in absence of plasticizers. These are unwanted properties for this application.

Commercially available cellulose-based plastics were not suitable due to water sensitivity and brittleness.

PLA plastics were not suitable for this application due to moisture sensitivity in warmer climates and lack of flexibility.

The lack of transparency makes paper materials and bio-based composites unsuitable for this application. These materials could have been used as components, but a mono
material construction was preferred due to easier recycling and a less complex manufacture process.

Bio-based polyethylene possessed the most suitable properties for this application, mainly because of its flexibility, water barrier properties and great manufacturability. The flexibility of polyethylene allows it to carry the garment when folded and does not creating permanent deformations, wrinkles, to the same extent as other candidates.

9.4 Concepts

Concept 1 is a premium clothes cover developed to be used from production to the store and then from the store to the customer's home. It has three purposes: protect the garment from production to retail, storing the garment and allowing the end-user to carrying it folded like a bag.

Concept 2 is a premium transport cover intended to be used from production to retail. The main purpose of the product is to protect the garment during transport, but the customer will also be able to carrying their cover folded in the hanger hook and use it to protect their suit when storing it at home. Concept 2 is cheaper to manufacture than Concept 1, however it is less functional in terms of carrying possibilities.
10. Discussion

*This chapter discusses the working process and proposes suggestions for further development.*

10.1 Working process

The greatest challenge in this project was to satisfy the requirements of the different application areas: transportation of the garment from production to retail and serving as a garment bag for the end-user. The transportation of the garment sets requirements such as inexpensive, light and thin, water resistant and partly transparent. While added value for the end-user requires a luxurious appearance and the functionality such as carrying possibilities. Further, using a bio-based material was equally important. This resulted in two solutions, one mainly intended for transport and another aimed at working for both application areas. Working on two parallel tracks was demanding but necessary in order to find out if it was possible making a product satisfying both application areas. However, a product working for transport and as a garment bag for the customer has tradeoffs and will not be as cheap as a clothes cover intended only for transport nor will it have as many functions and high quality as a premium garment bag intended for travelling.

The planning schedule was continuously modified, since the initial schedule was an estimate without sufficient knowledge about the project. The project deviated from the plan mainly depending on late material sample deliveries and a growing problem definition. Initially, the problem definition was an investigation of possibilities and limitations of using a bio-based material for a transport cover, which grew to realize a product concept for a transport cover in a bio-based material.

A lesson learned was to collect as much information possible about generated concepts before making a selection, for a fair assortment to be made. In order to evaluate how well a certain concept meets a requirement, a rough solution for the requirement must exist; otherwise the concept selection will be based on very uncertain grounds.

The execution of the perception study was affected by the time constraint. Correct material samples in terms of thickness and surface quality were difficult to get in time and sample deliveries were delayed. This resulted in stand-in materials and incorrect colors which decreased the reliability of some results and the applicability to the material selection. However, with support from discussions with the participants some test results could be easier interpreted and be applied to the material selection process.
10.2 Recommendations and further development

Additional studies are required in order to implement the final product concepts. First of all, construction problem-solving with manufacturers is necessary to go further with the product. Furthermore, price quotes from vendors are essential in order to conduct a cost estimation and a profitability study. In order to evaluate the performance of the product, a test batch tried out from production to retail would be necessary. A Life Cycle Assessment would be relevant to get an overview of the environmental impact under the product's lifecycle.
References


Appendix 1: Compilation of the web-based survey

This document includes the results from the web-based survey conducted at surveymonkey.com with 66 participants. The participants were students gathered from Facebook (16 p) and employees at Innventia AB (50 p). SurveyMonkey’s text analysis tool was used to identify the most frequently used words in the written answers. The survey was conducted in Swedish and this document is translated.

Gender:
47% Men
52% Women
1% Other

Age:

Do you own one or more clothes cover(s)?
84% of the men own one or more clothes cover(s).
69% of the women own one or more clothes cover(s).

How did you acquire it or them?

Men
31% bought it.
69% received one when they bought a suit.

Women
65% bought it.
35% received one when they bought a suit.
What are you using it/them for? Feel free to respond as detailed as possible. (47 answers)

Text analysis:
30% Travelling
26% Protect
23% Store
13% Transport

**Men** use it mainly for suits or tail-coats.

**Women** use it mainly for dresses, coats and evening wear.

Describe your clothes cover(s) as detailed as possible. For example material, appearance, functions etc. (44 answers)

Text analysis:
52% Zipper
36% Plastic
20% Black
11% Fabric
11% Nylon

Do you miss any functions/properties? In that case, which? (39 answers)

Text analysis:
13% Pockets
8% Light-weight
5% Foldable

Which functions/properties would you say are most important? (54 answers)

Text analysis:
43% Protection
19% Dust
15% Light-weight
15% Carry, transport, bring with you

Questions for those who do not own a clothes cover

Would you like to have a clothes cover? (16 answers)

19% Yes
19% No
62% Maybe

Why? (12 answers)

Text analysis:
75% Protect
25% Attic

Why not? (4 answers)

Two people answered lack of space and the others had no need for it.
Appendix 2: The full QFD-house

<table>
<thead>
<tr>
<th>Row</th>
<th>New Relationship Value in Row</th>
<th>New Relationship Value in Column</th>
<th>Quality Characteristics (a.k.a. “Functional Requirements” or “Musts”)</th>
<th>Demanded Quality (a.k.a. “Customer Requirements” or “Wants”)</th>
<th>Weight Importance</th>
<th>Relative Weight</th>
<th>Target or Limit Value</th>
<th>Difficulty (1=Easy to Accomplish, 10=Extremely Difficult)</th>
<th>Max Relationship Value in Column</th>
<th>Weight Importance</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>6.8</td>
<td>13.0</td>
<td>Attractive appearance</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>5</td>
<td>15</td>
<td>247.3</td>
<td>7.5</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5.5</td>
<td>8.0</td>
<td>Easy accessible hangtag</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>14</td>
<td>104.1</td>
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<tr>
<td>3</td>
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<td>Easy identification of garments inside</td>
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<td>O</td>
<td>▲</td>
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<td>91.1</td>
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<td>8.0</td>
<td>Attachable barcode</td>
<td>▲</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>114.8</td>
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</tr>
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<td>5</td>
<td>3</td>
<td>4.1</td>
<td>6.0</td>
<td>The garment should be able to breathe</td>
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<td>O</td>
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<td>4</td>
<td>9</td>
<td>117.0</td>
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<td>6</td>
<td>3</td>
<td>4.0</td>
<td>7.0</td>
<td>Protect garment from moisture</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>141.1</td>
<td>4.4</td>
</tr>
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<td>7</td>
<td>3</td>
<td>6.8</td>
<td>13.0</td>
<td>Protect garment from dust</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>143.8</td>
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<tr>
<td>8</td>
<td>3</td>
<td>4.1</td>
<td>6.0</td>
<td>Protect garment in case of drop</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>137.0</td>
<td>4.2</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>3.4</td>
<td>5.0</td>
<td>Protect garment from odors</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<tr>
<td>10</td>
<td>3</td>
<td>5.5</td>
<td>6.0</td>
<td>Light weight</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<td>11</td>
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<td>5.5</td>
<td>8.0</td>
<td>Thin</td>
<td>O</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<td>12</td>
<td>3</td>
<td>3.4</td>
<td>5.0</td>
<td>Possibility to carrying it</td>
<td>▲</td>
<td>O</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<td>13</td>
<td>3</td>
<td>5.5</td>
<td>6.0</td>
<td>Removable material</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<tr>
<td>14</td>
<td>3</td>
<td>5.5</td>
<td>8.0</td>
<td>Sustainable throughout life cycle</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<tr>
<td>15</td>
<td>3</td>
<td>4.8</td>
<td>7.0</td>
<td>Reasonable cost (purchase price &gt;5) x customer price</td>
<td>O</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<tr>
<td>16</td>
<td>3</td>
<td>5.5</td>
<td>8.0</td>
<td>The clothes cover must be &gt;10 cm longer than the garment in order to avoid wrinkles</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<td>17</td>
<td>3</td>
<td>5.5</td>
<td>8.0</td>
<td>Must be closed at the bottom if the garment would slide off the hanger</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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<tr>
<td>18</td>
<td>3</td>
<td>5.5</td>
<td>8.0</td>
<td>Must not be more than 2.5 cm wider than the garment</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>6.8</td>
<td>13.0</td>
<td>The material must not create garment discoloration</td>
<td>▲</td>
<td>▲</td>
<td>▲</td>
<td>4</td>
<td>9</td>
<td>&lt;30 gram</td>
<td>6.9</td>
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Figure 1. Part one of the QFD matrix
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**Figure 2.** Part two of the QFD matrix.
Appendix 3: Generated solutions from the workshop

Figure 1. The solutions from the workshop grouped in categories (in Swedish).
Appendix 4: Technical drawing of Concept 1

Figure 1 shows a manufacture proposal and basic measurements of Concepts 1.

Figure 1. A manufacture proposal and basic measurements of Concepts 1.
Figure 1 shows a manufacture proposal and basic measurements of Concepts 2.
Appendix 6: Information sheet from the perception study

Materialutvärdering

Ålder: ___
Kön:     Man □  Kvinna □  Annat □
Yrkesroll: ________________________

Bakgrund


Information om testet


Tack för att du tar dig tid att delta!
Appendix 7: Evaluation sheet from the perception study

Materialutvärdering

1 = överensstämmer inte alls
7 = överensstämmer helt

Lyxig
def. dyrbar, elegant

Maskulin
def. karakteristisk manlig

Premium
def. hög kvalitet och högt värde

Unik
def. ovanlig

Modern
def. nutidsenlig

Materialprov nr ____
# Appendix 8: Material specification from the perception study

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Sample</th>
<th>Information</th>
</tr>
</thead>
</table>
| 1             | ![Sample 1](image1) | Material: Low Density Polyethylene  
Finish: Shiny  
Color: White  
Thickness: 140 µm  
Dimension: 159x144 mm |
| 2             | ![Sample 2](image2) | Material: Low Density Polyethylene  
Finish: Matte  
Color: White  
Thickness: 170 µm  
Dimension: 156x150 mm |
| 3             | ![Sample 3](image3) | Material: Pulp-PLA Composite  
Finish: Crimped, fabric-like  
Color: Black/Dark grey  
Thickness: 600 µm  
Dimension: 153x125 mm |
| 4             | ![Sample 4](image4) | Material: Paper  
Finish: Smooth  
Color: White  
Thickness: 70 µm  
Dimension: 150x120 mm |
| 5             | ![Sample 5](image5) | Material: Coated polyester fabric  
Finish: Shiny  
Color: Black  
Thickness: 300 µm  
Dimension: 146x114 mm |
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
</table>
| 6 | Material: Nonwoven  
    Finish: Matte  
    Color: Black/Dark grey  
    Thickness: 440 µm  
    Dimension: 145x114 mm |   |
| 7 | Material: Pulp-PLA Composite  
    Finish: Rough, fabric-like  
    Color: Black  
    Thickness: 540 µm  
    Dimension: 154x106 mm |   |
| 8 | Material: Paperboard  
    Finish: Smooth  
    Color: White  
    Thickness: 420 µm  
    Dimension: 159x137 mm |   |
| 9 | Material: Paper  
    Finish: Rough  
    Color: Black  
    Thickness: 225 g/m²  
    Dimension: 210x99 mm |   |
| 10 | Material: PLA-film  
    Finish: Clear  
    Color: Transparent  
    Thickness: 40 µm  
    Dimension: 210x147 mm |   |
|   | Material: Low Density Polyethylene  | Finish: Hazy  
|   | Color: Semi-transparent  | Thickness: 60 µm  
|   | Dimension: 153x153 mm  |
|---|---|---|
| 11 | Material: Craft Paper  | Finish: Smooth  
|   | Color: White  | Thickness: 120 µm  
|   | Dimension: 150x135 mm  |
| 12 | Material: Low Density Polyethylene  | Finish: Clear  
|   | Color: Transparent  | Thickness: 70 µm  
|   | Dimension: 130x125 mm  |
Appendix 9: Results from the perception study

The results from the test group conducted by participants from Tiger of Sweden are presented in Figure 1-5. The test group consisted of 16 participants. A two-tailed t-test was used for the statistical evaluation with a significance level of 5% and a critical t-value of 2.13.

![Luxurious](image1)

**Figure 1** The average value for the attribute Luxurious for each sample.

![Masculine](image2)

**Figure 2** The average value for the attribute Masculine for each sample.
Figure 3 The average value for the attribute Premium for each sample.

Figure 4 The average value for the attribute Unique for each sample.
Potential consumer group

The results from the test group conducted by participants from the potential consumer group are presented in Figure 6-10. The test group consisted of 12 participants. A two-tailed t-test was used for the statistical evaluation with a significance level of 5% and a critical t-value of 2.20. Sample 13 was evaluated by 11 participants due to a mistake; accordingly the critical t-value for sample 13 was 2.23.

Figure 5 The average value for the attribute Modern for each sample.

Figure 6 The average value for the attribute Luxurious for each sample.
Figure 7 The average value for the attribute Masculine for each sample.

Figure 8 The average value for the attribute Premium for each sample.
**Figure 9** The average value for the attribute Unique for each sample.

**Figure 10** The average value for the attribute Modern for each sample.